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REPORT

ON THE

RECENT SEISMIC DISTURBANCES

WITHIN

CHEVIOT COUNTY IN NORTHERN CANTERBURY

AND

THE AMURI DISTRICT OF NELSON, NEW ZEALAND.

(NOVEMBER AND DECEMBER, 1901.)

By ***ALEXANDER McKAY, F.G.S., Government Geologist.***

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A Settler's Home: Glenkens House, Cheviot County. [Frontispiece.

REPORT

ON THE

RECENT SEISMIC DISTURBANCES WITHIN CHEVIOT COUNTY IN NORTHERN CANTERBURY

AND THE

AMURI DISTRICT OF NELSON, NEW ZEALAND.

Mr. A. McKay to the Under-Secretary for Mines.

Sir,— Wellington, 3rd February, 1902.

I have the honour to report that, as instructed, on the 20th November last I proceeded to Christchurch, and thence on the 22nd went to Cheviot for the purpose of examining the effects and investigating the cause of the earthquakes that, commencing on the 16th November, 1901, disturbed that district up till the 15th December of the same year.* The results of the examinations and the conclusions arrived at are embodied in the following report on the subject:—

Report.

Earthquakes result from a variety of causes, a variety perhaps greater than the comparative uniformity of the manifestations would seem to indicate. Earthquakes are common in regions of volcanic activity, and as preceding and accompanying volcanic eruptions they are popularly regarded as exclusively connected with such activities. At times of eruption in volcanic regions the earthquake is usually of an explosive character, the effect of a violent paroxysm of the volcano, of the explosion of gases, the crumbling or fall of rocks in the interior of the volcano or in its vicinity. In such cases the cause is local, and manifestly confined to a small area. The effects radiate outwards as from a centre, and at different distances, according to the position in depth of the impulsive shock. The resulting

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* Earthquakes have continued to be felt in the Cheviot district up till the date of this report.

agitation of the earth is transmitted upwards and outwards, at angles that lessen proportionate to the horizontal distance from the central point. Finally, the effects become so feeble as not to be observable by ordinary means, and where special appliances are not in use the limit of the disturbance is said to have been reached. At first, as the emergent angle lessens, the movement alters from a nearly vertical to a nearly horizontal direction at the surface of the earth, and before the force of the shock is materially lessened the low-angled waves produce great and often disastrous results near and on the surface of the ground. This variety of earthquake is most common in, but not confined to, volcanic regions. Gases may accumulate and explode, the roof of cavernous spaces deep in the crust of the earth may fall, or local strain may produce within a limited space such violent crushing of the rocks that powerful earth-tremors resulting from each of these causes may, and seemingly do, take place in regions far removed from the vicinity of active volcanoes. The point of explosion, fall, or crush producing the earthquake or the central point of the surface manifestations is called the epicentrum. The depth at which this lies from the surface is determined by the area of the circle and the angle of emergence on circles of different diameter, the observed equal time of the shock at different places determining the circle and vertical of the disturbance at the surface.

The above may not be an accurate epitome of the explanations determining the position of earthquakes of this sort, but it fairly represents the popular apprehension of such; and it is common enough to read that, with respect to particular shocks that have occurred, the epicentrum, as this would be located on a map of New Zealand, or a chart of the adjacent seas, was twenty miles east of Banks Peninsula, a like distance west of Greymouth, somewhere north-west of Lake Sumner, or in Cook Strait a stated distance from Stephen Island; and the depth from the surface at which the disturbance originated was ten, fifteen, or twenty miles, as the case may be.

There is an exactitude about this that is very far from reassuring, and, while the theory might apply and be proved fairly correct with respect to the earthquake shocks that accompanied the eruption of Mount Tarawera, and the explosions that destroyed the Pink and White Terraces in the hot-lakes district of Auckland, a doubt remains as to whether by such means the primal impulse that resulted in the recent disturbance of the Amuri district of Nelson and northern Canterbury can be located with similar exactitude.

From their very nature and their position at various depths in the earth's crust the actual moving causes of earthquakes cannot be studied by man. Their effects at the surface may be, and reason-

able inferences may lead to conclusions probable enough. It is known that large areas of land are being elevated above the level of the sea, while others are being depressed, and where such rising and sinking areas border upon each other great crumpling or rupture of the rocks must take place. The production of faults under heavy strain is unavoidable, and the consequent vibrations of the rocks adjacent constitute an earthquake.* This may be slight, moderate, or severe, local or far-reaching, superficial or deep-seated, according to circumstances. Earthquakes thus arising may be grouped under two heads—namely, first, those that are far-reaching and comparatively uniform in their action; and, second, those of a more local origin, and characterized as being slight or severe within short distances.

There are thus three classes of earthquakes the cause and nature of which may be fairly apprehended, even if they are far from being demonstrated or demonstrable. These are:—

First—Those which result, as earth-tremors, from explosions or other causes confined to a small space;

Second—Earthquakes resulting from or consequent on the rupture within areas of great earth-strains, and which in their action are uniform and widely extended;

Third—Earthquakes that are the result of more local and superficial movements of the earth's crust, and characterized by a greater variability of intensity; and

Fourth—Earthquakes arising from causes that are obscure, and not conforming to one or other of the three preceding classes.

Each of the three classes of earthquakes particularly specified are or have been exemplified by their occurrence in New Zealand: The first in the volcanic district of the central part of the North Island, where in 1886 the earthquakes accompanying the eruption of Tarawera Mountain and the destruction of the White and Pink Terraces were extremely violent in the vicinity of the explosive centre, but rapidly became less so as the distance from the source of the disturbance increased. North-west and south-east of Tarawera the earthquakes, as powerful shocks, did not extend above twenty miles outwards from the point of explosion. They were felt to much greater distances along the north-east and south-west line between White Island and Ruapehu, this being the line of volcanic activity within which Tarawera lies, and earthquake shocks along this were felt with considerable violence as far to the south-west as

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* There seems to be some confusion with respect to the earthquake and its cause; and it may be here explained that, as far as this report is concerned, the cause is not the earthquake.

Hunterville, in the Rangitikei Valley. Theoretically, in equal media the effects of the explosions in Tarawera should have been equal in equal distances, and the conveyance of the shock to greater distances along the north-east and south-west line of weakness is explainable by what is obvious.

The second class of earthquakes resulting from rupture within areas of great earth-strains, and which in their action are uniform and widely extended, it may be assumed, find a cause in the general shrinkage of the earth due to the loss of heat; but, however difficult of explanation, when earthquakes of this variety do occur they are easily distinguished from those of the first class, and need not be confused with such as should be classified under the third. They are evidently deep-seated in comparison with the other two.

The third class of earthquakes may have some connection with the second, but there are superficial and visible causes that operate towards the production of greater local intensity, and their effects in modifying the orography of the country are far more apparent. In New Zealand they appear to be connected with certain great lines of fracture that may be traced in different directions, usually parallel or sub-parallel to the great mountain-chains of both Islands. In cases, and it may be said in most cases, the existence of the mountain-chains as they now appear is due to their influence. Within the historic period—*i.e.*, since the settlement of the country by Europeans—paroxysmal periods of disturbance have been frequent, and something like a periodicity in their occurrence seems to be indicated; but, as the recorded disturbances have affected at different times different distinct lines of fracture, a periodicity of their occurrence along any particular line cannot be formulated.

The first recorded series of violent earthquakes, affecting the north-east district of the South Island, took place in 1848. The seat of the disturbance appears to have been the Awatere Valley, in the Marlborough Provincial District; but violent earthquakes were experienced in Nelson, and in Wellington on the opposite side of Cook Strait. This series of earthquakes formed or reopened a line of fracture extending nearly the whole length of the Awatere Valley, along which the rupture and displacements can be traced even now.

In 1855 violent earthquakes took place in both Islands of New Zealand, and were notably experienced in and around the City of Wellington. They also were felt with great violence in the north-east district of the South Island from Cape Campbell to the mouth of the Clarence River. In this case the disturbance seems to have been due to or resulting from a reopening of a line of fracture running along the eastern base of the Inland Kaikoura Mountains,

which line of fracture continued across Cook Strait, passes through the City of Wellington, and is thence continued through the Wellington District north-east into that of Hawke's Bay. This earthquake elevated the eastern shore of Cook Strait and the Rimutaka Mountains 9ft. in a single night, and reopened a line of fracture running along the eastern base of these mountains, the supposed continuation of which line, in the South Island, lies to the east of the Great Clarence fault.

In 1866 the more easterly line of fracture was again reopened, and violent earthquakes were experienced in the northern part of east Wellington and in the Hawke's Bay District. At this time the Waipawa River abandoned its bed and assumed a new course, some parts of which are three miles distant from the old channel in which it previously flowed. Vertical displacements to a considerable amount took place at this time in various parts of the Hawke's Bay District.

Minor disturbances affecting northern Canterbury took place in 1870–71 and 1884. These, however, may be disregarded, and it was not till 1888 that the next disturbance of great violence took place. This happened in the Amuri district of Nelson, but the effects were felt with great force as far to the south as Christchurch, the provincial town of the Province of Canterbury. This series of shocks reopened a line of fracture running nearly east and west from the main water-divide, between the east and west coasts of the South Island, along the Hope and Waiau-ua Valleys, and along the Hanmer Plain to the Hoosack Saddle at the northern end of the Leslie Hills. This earthquake threw down part of the spire of Christchurch Cathedral, and was strongly felt in many parts of northern Canterbury; but its greatest force was felt in the part of the Amuri district already described. In this district the greatest violence of the earthquake was felt along a line of dislocation running nearly east and west along the Hope and Waiau-ua Valleys, and through the Hanmer Plain to its eastern border abutting against the west slopes of the Leslie Hills. Beyond this to the eastward, though earthquake shocks of very considerable force were felt, these were insufficient to reopen the old earthquake fractures east of the Hoosack Saddle in Lottery Creek, or Sherwood Forest in the valley of the Mason River. The disturbance was violent over the Hanmer Plain and in the Waiau-ua Gorge, and did much damage to buildings as far as Montrose Station, at the lower end of the gorge; but its greatest force was exerted in the Waiau-ua Valley, above the Hanmer Plain, to the junction of the Hope River, and thence west along the Hope Valley some twelve miles to the junction of Kiwi Creek, at which point, the river

turning to the north, the line of earth-fracture is continued west into the mountainous and bush-clad region of the main water-divide of this part of the South Island. At and near Glenwye, in the Hope Valley, this series of earthquakes displayed the greatest violence and most destructive force. The principal shock took place on the morning of the 1st September, 1888.

No serious disturbance took place along this or other lines of fracture traversing the north-east part of the South Island till November, 1901, when on the 16th of that month a very violent shock of earthquake occurred in the coastal district east of the Mason River and Hurunui–Waiau-ua Plain. Its greatest force seems to have been exerted between the Conway and Waiau-ua Rivers, but it was also felt with great violence between the Waiau-ua and the Hurunui, from the coast-line to the western lower slopes of the Lowry Peaks Range and the eastern border of the Hurunui–Waiau-ua Plain.

The principal shock of the 16th November was followed by a great number of violent but lesser shocks, which continued up to the commencement of 1902. The first of this series of shocks was felt at great distances to the north and to the south — from Wellington to Dunedin—but as a destructive earthquake between Kaikoura to the north and Christchurch to the south. At Kaikoura the damage was confined to the rending and fall of a few brick chimneys. In Christchurch little damage was done to buildings other than the shifting of the outer casing of the upper part of the Cathedral spire, which suffered severely during the earthquakes of 1888. On this occasion the damage was less, and consisted in the displacing of the facing-bricks of the upper part of the spire a few inches only.

Within the Settlement of Cheviot and the Township of Mackenzie scarcely a chimney of any kind was left standing, and where the buildings consisted of brick, cob, or sun-dried brick, with one exception, they were razed to the ground. North of the Waiau-ua the station-buildings on Parnassus, Mendip, and Hawkswood Runs suffered to a greater extent than the wooden buildings on the Cheviot Estate, and, as in the latter locality, cob-and-clay buildings were utterly demolished. The Cheviot roads and bridges suffered to a considerable extent, and of this kind of damage done more particularly may be mentioned the fall of great bodies of rock from the sea-cliff between the mouth of the Jed River and Port Robinson, along which a dray-road from Mackenzie to Port Robinson (the shipping-place of the settlement) had been made. Earth-rendings are for the most part confined to where the roads have been cut along sidelings, or where near the banks of streams rents have been produced between the soft lower grounds and the harder and drier terraces adjacent. True rock-rendings are rare, and nowhere are

they continuous for any great distance, and they do not occur so arranged as to indicate the existence of a principal and long-extended earth-fracture.

At Stonyhurst, a few miles south of the mouth of the Hurunui River, some damage has been done to the station-buildings, and portions of cliffs on the coast-line have fallen ; but it is evident that the earthquake was felt with less severity at this place than farther to the north.

At Cabbage-tree Flat and at Amberley the damage was confined to the fall of a few chimneys.

At Waikari, Culverden, Rotherham, and the Waiau the effects of the great shock were not serious beyond the loss of a few chimneys and lighter movables inside houses. Near the Waiau, on Dog Creek, Lyndon Run, a number of earth-rents were formed, but these were of the character of rendings between the soft low grounds and the harder terrace-banks, as happened in the neighbourhood of Mackenzie, on the Cheviot Estate.

On the Stanton, true rock-rendings appeared near the lower end of the valley. These crossed the valley in an east-and-west direction, and their projection east would carry them to a point in the Leader Valley where a local centre of disturbance seems to be indicated by excessive rending of the surface both in the low grounds of the river-bed and on the spurs adjacent, more especially on the western side. In the middle part of the Stanton Valley great slips took place, and at one particular locality the weight of a slip from the north-west exerted such pressure on the Tertiary clays of the low grounds that there arose a ridge some 12 ft. in height, and in this way the flow of the waters was obstructed, and a narrow lake 25 chains in length was formed. This elevated ground terminated towards the east in a steep bank, having a slope of 30° to 35°, and over this part the surface was broken and telescoped one part under or over the other. In the Upper Stanton Valley there were many instances of the fall of gravels and Tertiary clays from the precipitous banks of the river, but so far as examined few earth-rendings were to be seen.

In the Leader Valley, between the junction of the Castaly and Mendip Hills Station, there were rents along the river-bed, on the slope rising on to the station flat, and in the neighbourhood of the homestead. None of these were of a very imposing character. The slips from the high banks of the river, from the hillsides and the broken ground on the steeper hill-slopes, were all of a superficial character, but these, far more than the true rock-rendings, gave an impression of the great violence of the earthquakes. A mile below the junction of the Castaly true rock-rendings appeared in the bed

of the Leader and on the spurs on both sides, more especially on the west side of the Leader Valley.

Nearer to Parnassus Station rents of any kind disappeared. They, however, reappeared near the junction of the Leader with the Waiau-ua, and on the river-flat above the junction. The station-buildings at Parnassus and Mendip Hills Stations suffered severely. Cob walls at Parnassus were thrown down, and two cottages were thus wholly wrecked. Wooden buildings, though severely shaken, withstood the shocks. At Mendip Hills the earthquake did more damage to structures in wood, as may be gathered from the appendix to this report. Neither at Hawkswood nor at Ferniehurst Stations were the effects of the earthquakes felt with the severity experienced at Mendip Hills Station or at Parnassus.

Along the Mason Valley to the Whale's Back, at and beyond the Conway, there is little of an extraordinary character to report. One earth-rent appears on the roadside on the north bank of the Conway, and great clouds of dust were raised along the line of the Kaikoura fault, between the Conway and the saddle leading from the Upper Towy into the Mason watershed. North of the Conway the force of the great and succeeding shocks rapidly decreased, and from the crossing of the Charwell to Kaikoura there are no visible signs of recent earthquake action.

The greater force and greater frequency of the earthquakes, it is evident, was along a narrow belt of country between the coast ranges and the parallel extension of the Lowry Peaks Range, Mount Parnassus, and Mount Stuart Range, that lie to the westward, and divide the low grounds of Cheviot and the Leader Valley from the parallel extension of the Hurunui Plain.

The assumption that these earthquakes had their initiative along an eastern extension of the line affected by the earthquakes of 1888 in the Hope and Waiau-ua Valleys has not been borne out by the observations made, and so far I was unable to trace an extension of the fault-line east-north-east from the forks of Lottery Creek. Neither the Kaikoura line of fault nor the Great Clarence fault seem to have been further displaced by the earthquakes of November last, and, except in a general way, it cannot be said what the originating cause has been.

Referring to the connection between earthquakes and the existing and ascertained great lines of fault that run through the Marlborough and Amuri districts of the north-east part of the South Island, and more particularly to the western extension of the Kaikoura fault, this from the slopes of Mount Sherwood should be continued towards the east-north-east, between Mount Cookson and the Whale's Back, and along the north-west slopes of the Mount Stuart Range to the

Conway River. Beyond the Conway the same line continued would reach the sea-coast at Goose Bay, six miles north of Amuri Bluff. This part of the line has not been geologically explored, and during the past month an attempt to trace the line in an east-north-east direction from Lottery Creek failed, and I was compelled to fall back on the previous determination that at Lottery Creek the line of fault turns more to the north, and runs along the eastern lower slopes of the Mount Sherwood Range, and by way of the Upper Mason reaches into the Conway watershed, crossing that river where it leaves the mountains in which it takes its rise.

The connection between earthquake disturbances of this class and continuous and long-extended lines of fracture along valleys bounded by mountain-ranges was manifested in the case of the re-opening of the Awatere line of fracture in 1848, and of a like opening along the eastern base of the Rimutaka Mountains in 1855; but it was not till 1885 that the coincidence and identity of these superficial rendings with great lines of fault was established. In that year the writer made a geological examination of the eastern part of the Marlborough Provincial District, during which it was discovered that a great line of fault ran along the south-eastern, middle, and lower slopes of the Inland Kaikoura Mountains from the Ure River to the junction of the Elliot with the Clarence, south-west of which the same line could be traced on the opposite or south-east of the Clarence Valley to the Hoosack Saddle, and further to the south-west across the Waiau-ua Gorge at Marble Point.

As far as the Palmer River the fault-line can be traced continuously. To the south-west of that stream the difficulties of mountain travel prevented it being followed closely. From the Ure the same line was traced north-east into the upper valley of the Flaxbourne River, and thence less clearly to the shores of Cook Strait in Cloudy Bay. Along the higher part of the Inland Kaikoura Mountains the fault-line can be clearly followed by surface indications of displacement within very recent times, and the numerous geological sections to be obtained along the courses of the various small rivers draining from the mountain-range show that enormous vertical displacement has taken place along this line.

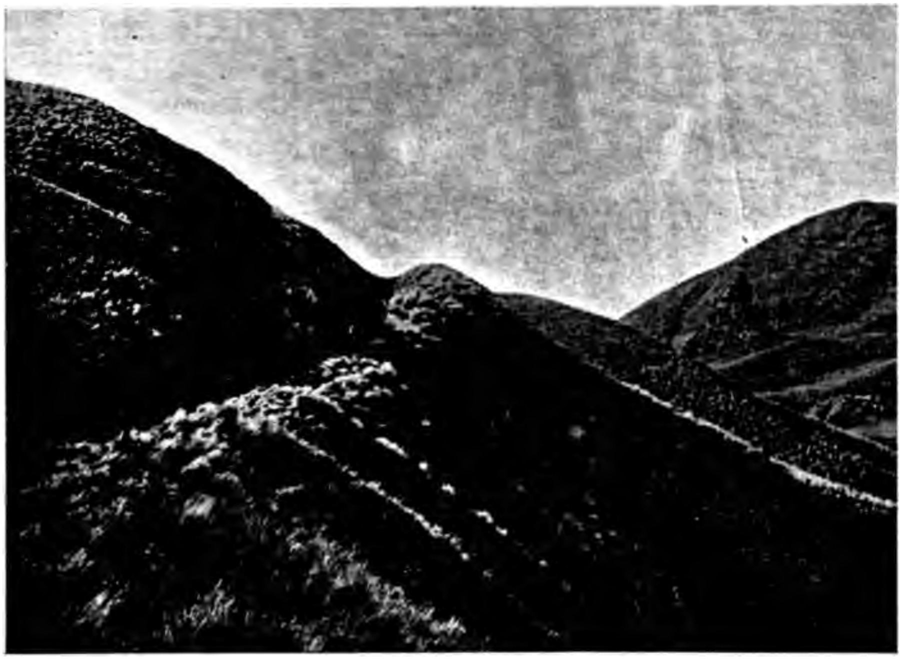
A great thickness of Cretaceous rocks representing the coal-formation of New Zealand, closed by an enormous development of chalky limestone succeeded by clay marls, constitutes the sequence which, varying from 8,000 ft. to 12,000 ft. in thickness, dips so as to pass under the Palæozoic rock of the higher part of the mountain-range at angles varying from 30° to 50°. The younger rocks are followed by an enormous development of conglomerates and breccias formed of rocks foreign to the district, which finally pass under the Palæozoic

rocks at an angle of 60° to the west, this being the hade of the line of fault. Between Coverham and the "Bluff" these rocks are developed along the slope and downs immediately at the foot of the range, Palæozoic rocks separating them from the lower part of the valley and the channel of the Clarence River.

In vertical section the shear of the fault-line may be traced from 3,500 ft. above the sea to about 1,000 ft. above sea-level; and along it the line can be traced by a sharp depression across the valleys of mountain-streams and up the opposite slope to the next saddle without difficulty. In this way it crosses the Mead, the Dee, the Branch, the Dart, the Muzzle, and many lesser mountain-streams. The vertical displacement along the fault-line cannot be less than 10,000 ft., and may be considerably more; but this is a question that for the present may be left out of consideration.

In the same district other faults of great displacement were noted on the coast, between the Saw-tooth Range and the coast-line, between the Kekerangu and the mouth of the Clarence River; and the same faults are continued south along the eastern base of the Looker-on Mountains. Immediately abreast of Kaikoura, from various causes, they are obscure and difficult to trace; but more to the south from the Shearing Reserve, along the eastern base of the Mount Clear Range, a line of fault is traceable across the Charwell and Conway and west of the Whale's Back into the watershed of the Mason River. This is lost in the bush-clad country of Sherwood Forest, and was by me supposed to have taken a more westerly course along the flanks of Mount Sherwood to the Upper Lottery, where heavy faulting and modern displacements are again to be seen. From Lottery Creek this line, or a new line, of fracture follows a nearly east-and-west course—the exact direction is a little south of west, magnetic—and this it is that, crossing the Hanmer Pass, is obscure in its course along the plain itself, but becomes very evident in the Waiau-ua Valley west of the Horse Spur, and is continued along the terraces on the south side of the river to the junction of the Hope with the Waiau-ua. It runs along the Hope Valley to the junction of Kiwi Creek. This, in 1885, I believed to be a continuation of the Kaikoura fault, and recent investigations have confirmed me in that opinion.

The survey of the Kaikoura Mountains was continued during the season of 1886–87, and that year the Awatere Valley was examined. A line of earthquake fracture was traced from the lower part of the Awatere Valley to Molesworth Station, near the source of the river. At every point it was well marked, and everywhere was coincident, or nearly so, with a line of fault comparable with that on the east side of the Inland Kaikoura Mountains. Here the



Fault-line and Earthquake Rent, Lottery Creek, Amuri County.

[To face p 10.

rocks of Cretaceous age were the same in character, saving that the upper marly clays were absent, as also was the great conglomerate and breccia formation, and the chalky limestones, as the highest in the sequence, were in contact with the Palæozoic rocks on the west side of the fault-line and earthquake rent.

During 1886–87 and this season I have taken many photographic views of the earthquake rents and coincident lines of fault, and established, as I consider, the identity of the two. In reporting the conclusions arrived at on the termination of these surveys, I had to state what might to some appear almost incredible, but what I nevertheless believed to be true—namely, that the Kaikoura Mountains, inland and seaward, and the continuation of the latter along the Mount Clear and Cloudy Range to Mount Sherwood, had been elevated to their present height from a moderately elevated plateau solely by earthquake action, and this since the commencement of Pliocene times. I soon afterwards found that the same hypothesis explained fully many puzzles relating to the physical geography and geology of the west and north-west of the Nelson District, and, indeed, the whole of the South Island north of a line drawn from the mouth of the Rakaia to that of the Hokitika River.

Although these facts were stated by me in 1885 and again in 1889, the theories which they supported seem to have found but little favour from co-workers in New Zealand; the facts themselves, if they be accepted, are so with something like distrust, and the study of the connection that exists between earthquakes and the great fault-lines and earth-fractures that traverse the Marlborough Provincial District and Amuri district of Nelson has not received that attention which the subject deserves.

This is a matter of little consequence to me; the loss is not mine, and the triumph of truth is certain. For the time being the fashion is to deal with all New Zealand earthquakes as having their cause and impulse within very restricted limits, whence the effects are displayed at and near the surface in the various phenomena that, strictly speaking, do, after all, constitute the earthquake. I have no quarrel with such studies. On the contrary, correctly applied, they obviously are of very great importance; and, as already pointed out, there is a class of earthquake to which they specially apply—viz., those accompanying volcanic eruptions and such as are of an explosive character.

The theory of a focal point for such disturbances for very obvious reasons must be accepted, but when this is used to explain the facts in connection with another class of earthquake there is danger that all the facts do not fit in with the theory, and that those that do not conform are simply regarded as subject to error in the recording of them.

Then, again, different methods may be pursued in the collection of facts, and when obtained these may be regarded as of different values. One student of the subject tells me that earthquakes are best studied at a considerable distance from the scene of their occurrence; and another writes that the manifestations at the surface, when these consist of rents, fissures, and dislocations, are not a measure of the force of the earthquake, by which, I suppose, I am to understand that earthquakes originating at different depths in the earth, though they might display precisely the same effects at the surface, must yet differ greatly in the amount of resistance they have overcome, and consequently in the force of the moving cause. Just so; but I have already said that the cause of the earthquake and the thing itself are different.

This report deals with a variety of earthquakes supposed to be different from those that originate in the fulminate of a percussion-cap, or, were it possible, on the apex of a mathematical point; and, in support of a different view, I hold that the Cheviot and Amuri earthquakes of the latter part of 1901 and the first two months of 1902 belong to the third of the different classes which have been discriminated and stated in the earlier part of this report. In this contention I make bold to claim support in the writings of one who must ever be regarded as a foremost writer on geology, and its most philosophical exponent.

Sir Charles Lyell, in his "Principles of Geology," 10th ed., Vol. ii., pages 82 to 89, has given an account of the recorded earthquakes in New Zealand up to and including that of 1855, and to some it may seem that in this report I but restate the facts there given, and add to the views which the author has expressed, and, if so charged, I remain content. The passage referred to is as follows:—

"In no country, perhaps, where the English language is spoken have earthquakes, or, to speak more correctly, the subterranean causes to which such movements are due, been so active in producing changes of geological interest as in New Zealand. The convulsions which have agitated this archipelago since it was first known to whalers or settlers have visited different districts in succession. The Rev. R. Taylor, many years a missionary in New Zealand, states that the shocks of 1826, 1841, and 1843 expended each of them their chief violence in distinct areas. In the year 1823 there was a small cove called the Jail, about eighty miles north of Dusky Bay" [Sound], "much visited by sealers, for it afforded suitable anchorage for their vessels, being sheltered by lofty cliffs, and having deep water so close to the shore that they could step out of their boats on to the rocks.

"After a succession of earthquakes in 1826 and 1827, so complete was the transformation of this coast that its former features could no longer be recognised; the cove had become dry land, and trees were seen under the water near the coast, having probably been carried down by landslips into what was previously deep water, for large masses are said to have slid down from the hills into the sea. The same writer informs us that in 1847 the hull of a vessel was discovered on the western coast of the South Island. It was lying 200 yards inland, and was supposed to be the 'Active,' which was lost in 1814. A small tree was growing through its bottom, and Mr. Taylor suggests that the coast had risen so as to cause the ocean to retire to a distance of 200 yards from the old shore-line, where the vessel had been stranded; but a more precise investigation of the locality will be required before we can feel sure that the vessel was not carried by a wave raised by the earthquake, for such waves have in modern times left much larger ships high and dry in the interior of Peru and some other countries.*

"The Natives" [the Maoris] "are said to have told our first settlers that they might expect a great earthquake every seven years; and, although such exact periodicity has by no means been verified, the average number of violent shocks in a quarter of a century seems not to have fallen short of the estimate here referred to.

"In the course of the year 1856 I had an opportunity of conversing in London with three gentlemen, all well qualified as scientific observers, who were eye-witnesses of the tremendous earthquake experienced in January of the preceding year in New Zealand. These were Mr. Edward Roberts, of the Royal Engineers Department; Mr. Walter Mantell, son of the celebrated geologist; Mr. Frederick A. Weld, a landed proprietor in the South Island. The earthquake occurred in the night of the 23rd January, 1855, and was most violent in the narrowest part of Cook Strait, a few miles to the south-east of Port Nicholson; but the shock was felt by ships at sea a hundred and fifty miles from the coast, and the whole area shaken of land and water is estimated at 360,000 square miles, an area three times as large as the British Isles. In the vicinity of Wellington, in the North Island, a track of land comprising 4,600 square miles (not much inferior to Yorkshire in dimensions) is supposed by Mr. Roberts to have been permanently upraised from 1 ft. to 9 ft. There was no perceptible elevation on the coast sixteen miles north of Wellington, but from that point to Pencarrow Head, on the east side at the entrance of Port Nicholson, the amount of upheaval went on increasing somewhat gradually, till it reached a vertical height of 9 ft. along the eastern flank of the Rimutaka Mountains.

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* Rev. R. Taylor, "New Zealand and its Inhabitants," London, 1855.

"This range terminates in Cook Strait between Port Nicholson and Palliser Bay, in a lofty coast rising rapidly to heights about 4,000 ft. above the sea. Here the vertical movement ceased abruptly along the base of these hills, not affecting the low country to the eastward called the Plain of Wairarapa. The points of minimum and maximum elevation from north-west to south-east in the district above alluded to are about twenty-three miles apart, which therefore expresses the breadth of the upraised area. Mr. Roberts was employed professionally, before and after the 23rd January, in executing several Government works in the Harbour of Port Nicholson and on the coast, and had occasion to observe minutely the changes in the level of the land, which took place at various points, and especially in the sea-cliffs called Mukamuka, twelve miles south-east of Wellington, where the eastern flank of the Rimutaka Range, before described, terminates southwards in Cook Strait. Here a distinct line of fault was observed, the rocks on one side being raised vertically 9 ft., while the strata on the other side of the fissure experienced no movement. The uplifted mass consists, according to Mr. Walter Mantell, of argellite, having the ordinary composition of clay-slate, but not laminated. It presents a cliff several hundred feet high towards the Strait, whereas the horizontally stratified Tertiary strata exposed to the eastward form a comparatively low cliff, not exceeding 80 ft. in height. These Tertiary strata, which are of marine origin, did not, as already stated, participate in the upward movement. Mr. Roberts was able to measure accurately the amount of permanent upheaval in the older formation by observing the altered position of a white band of millepores with which the surface of the rock below the level of lowtide had been coated. This white zone a few hours after the earthquake was found to be 9 ft. above its former level. Previously to the shock there had been no room to pass between the sea and the base of the perpendicular cliff called Mukamuka, except for a short time at low water; and, as the herdsmen were obliged to wait for lowtide in order to drive their cattle past the cliff, Mr. Roberts was engaged in constructing a road there. But immediately after the upheaval a gently sloping raised beach, more than 100 ft. wide, was laid dry, affording ample space at all states of the tide for the passage of man and beast.

"The junction of the older and newer rocks along the line of fault above described is marked in the interior of the country by a continuous escarpment running north and south along the base of the Rimutaka Mountains, where they present a steep slope towards the east, or towards the great plain of the Wairarapa, formed of the modern Tertiary deposit before mentioned. The course of the fault along the base of the escarpment was rendered visible by a nearly

perpendicular cliff of fresh aspect, 9 ft. in height, and traceable in an inland direction to the extraordinary distance of about ninety miles, according to information given by Mr. Borlase, a settler who lived in the Wairarapa Valley, about sixty miles north of Cook Strait. It was marked, moreover, in many places by an open fissure, into which cattle fell, and could not in some cases be recovered; or by fissures from 6 ft. to 9 ft. broad, filled here and there with soft mud and loose earth.

"At the same time that this vertical movement took place, on January 23, the Harbour of Port Nicholson, about twelve miles to the westward of Mukamuka Cliff, together with the valley of the Hutt, was raised from 4 ft. to 5 ft., the greater elevation being on the eastern and the lesser on the western side of the harbour. A rock called the Balley Rock, a short distance from Evans Bay, was formerly 2 ft. under water at the lowest tides, and, a vessel having touched upon it, a buoy had been placed over it to mark its position. This rock projected, after the shock, nearly 3 ft. above the surface of the water at lowtide. The rise of the tide in the Hutt River was sensibly diminished by the earthquake. At the time of the convulsion great waves of the sea rolled in upon the coast, and for several weeks the tides were very irregular. Dead fish were left by a wave on the racecourse at Wellington, and Mr. Mantell states that others were also met with by several vessels in Cook Strait, floating on the sea in surprising numbers, some of them species never seen before by the fishermen.

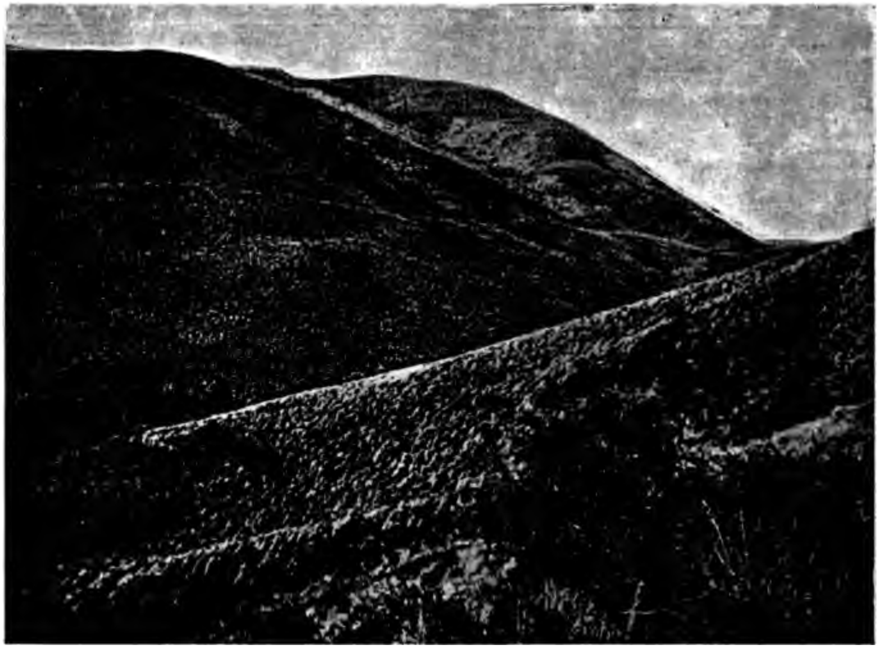
"Mr. Weld, who resided south of the Strait, in the South Island, informed me that, besides experiencing there the shock of the 23rd, he felt another next morning of equal violence, and waves of the sea rolled in along the coast for a distance of fifty miles. At a place called 'the Flags,' between Cape Campbell and Waipapa, some men were loading a vessel with wood, when they saw distinctly an earthquake approaching them from a point called 'the White Rocks,' three miles to the northward. Its approach was rendered visible by the rolling of stones from the top of the cliffs, and also by landslips and clouds of dust, and by the accompanying sea-wave. Upon the whole, it appears that the area convulsed in the South Island was not so extensive as that upheaved around Wellington, also that to the south of the Strait the direction of the movement was reversed, being for the most part a downward one. The Valley of the Wairau, with parts of the adjoining coast, subsided about 5 ft., so that the tide flowed several miles farther up into the Wairau River than it formerly did, and ships taking in fresh water were obliged to go three miles farther up the river to obtain a supply than they did before the earthquake.

"There was no volcanic eruption, whether in the northern or southern Island, at the time of these events; but the Natives allege that the temperature of the Taupo hot springs was sensibly elevated just before the catastrophe.

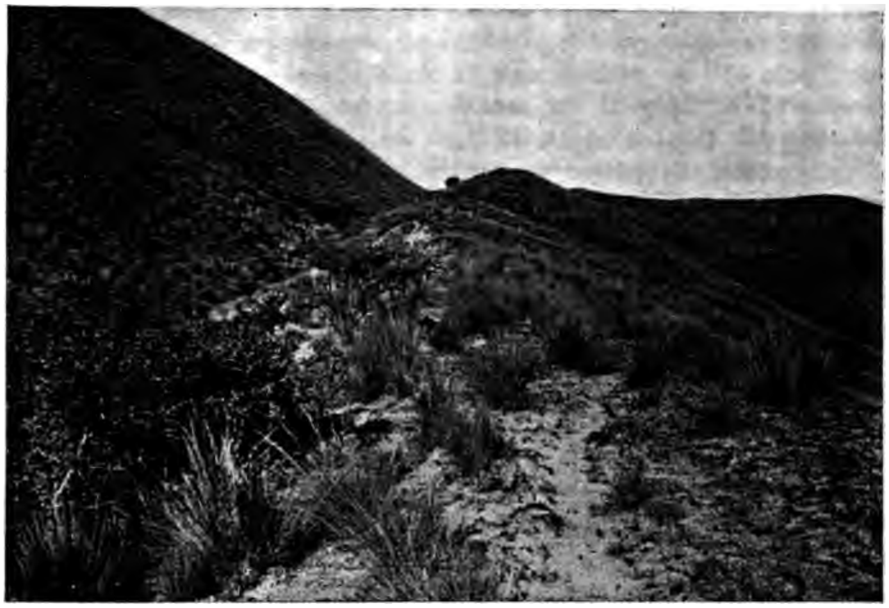
"I will now conclude this sketch of the changes produced in 1855 by observing that a question arose as to whether in the region about Port Nicholson the land, after it was upheaved in January, sank again to some slight extent or a few inches in the course of seven or eight months, or before September, 1855. When Mr. Roberts left New Zealand, three months after the earthquake, there had been no sinking of the upraised land, and he felt persuaded that he could not have failed to notice even a slight change of level had any occurred. He ascertained ten weeks after the shock that there had certainly been no subsidence whatever on the coast at Pencarrow Head, and the tides were so irregular long after the earthquake, in the Harbour of Port Nicholson and elsewhere, that the supposed partial sinking of the coast which some believed to have taken place might perhaps be deceptive. It is surprising how soon the signs of a recent change of level on a coast are effaced to all eyes but those of the scientific observer, especially where there is a rise and fall of the tides. Rocks newly exposed soon begin to weather, and vegetation spreads over the emerged land, and a new beach with all the characteristics of the old one is formed in a few months along the sea-margin.

"The geologist has rarely enjoyed so good an opportunity as that afforded him by this convulsion in New Zealand of observing one of the steps by which these great displacements of the rocks, called 'faults,' may in the course of ages be brought about. The manner, also, in which the upward movement increased from north-west to south-east explains the manner in which beds may be made to dip more and more in a given direction by each successive shock.

"An independent witness of the earthquake of January, 1855, a civil engineer, says, in a letter to Mr. Robert Mallet, that 'the first and greatest shock of January 23 lasted about a minute and a half. All the brick buildings in Wellington were overthrown, as well as the bridge over the Hutt. The hillsides opposite Wellington, those of the Rimutaka Range, were much shaken, as evidenced by the many patches with which they were chequered, fully to the extent of one-third of their surface, whence trees had been shaken off.' The ground in this range, he says, was more violently shaken than in Wellington, and the direction of the shock was north-east and south-west, agreeing with that of the chain of hills. After the shock the tide did not come at high water within 3 ft. or 4 ft. of its former height.



Fault-line and Earthquake Rent, Awatere Valley; not disturbed since 1848. [To face p. 17.



Fault-line and Earthquake Rent, Awatere Valley: Section across Fault-line.

[To face p. 17.

"Mr. Weld was in the South Island during the previous earthquake of 1848, and he informed me that a great rent was there caused in a chain of mountains, varying in height from 1,000 ft. to 4,000 ft., which runs southward from the White Bluff in Cloudy Bay, and may be considered a prolongation of the Rimutaka or Tararua chain above alluded to. This fissure of 1848 was not more than 18 in. in average width, but was remarkable for its length, for it was partly traced by Mr. Weld, and partly by observers on whom he could rely, for sixty miles, striking north-north-east and south-south-west in a line parallel to the axis of the chain."

In this report, which deals mainly with the Cheviot and Amuri Counties of the north-east district of the South Island, it would be out of place to discuss the influence of fault displacements caused by earthquakes over the whole of New Zealand, or the modification of the principal mountain-ranges that are traceable to the same cause; but, as it is quite clear that Sir Charles Lyell did not doubt the connection of fault displacement and earthquake action conjointly as factors producing rapid and great changes in the relative levels of land and sea and the permanent upheaval of mountain regions, nor doubt that to the frequent repetition of such action mountain-chains might owe their origin and continued existence, I am thus emboldened to state my views with respect to the origin of the present features of the Marlborough and Amuri district particularly, and in a more general way of the whole of the South Island north of the Rakaia and Hokitika Valleys. In so doing I am aware that I shall express opinions not likely to meet with indorsement in every quarter; but for the present this is a matter of temporary concern only, as I shall shortly deal with the whole question of the origin of the present configuration of New Zealand, and the credit of the correct theory will be apportioned, to the best of my judgment, to those the most deserving of the same.

Widespread over the northern part of the South Island is a chalk-limestone known indifferently as the Amuri limestone on the east coast of the Island, or the Cobden limestone on the west coast. This, though indurated in places to a condition harder than ordinary chalk, is approximately of the age and otherwise has many of the characteristics of the chalk of England. It abounds in flints, and is essentially a foraminiferous limestone, which, if not deposited in abysmal depths, at least was accumulated over the floor of a wide open sea. It maintains its chief characteristics over a distance of more than two hundred miles east and west and north and south. Such a rock could not have been deposited in the narrow sounds penetrating a mountain land. Nor is there any real evidence that such was the case. Yet it is now found stretching up the deep mountain-valleys

of the Marlborough District—in the case of the Clarence Valley from its mouth for a distance of forty miles between high mountain-ranges, the peaks of which reach to nearly 10,000 ft. above sea-level, and yet are not ten miles apart. The same rocks appear on the east slopes of the Looker-on Mountains at various elevations, but to the west are almost everywhere terminated along a line of fault.

As the Seaward Kaikouras are followed to the south along Mount Clear and the Cloudy Ranges, another range—the Raglan-Hawkswood and Cheviot Coast Range—interposes between the continuation of the Seaward Kaikoura or Looker-on Mountains and the sea, and along the eastern base of this, between Amuri Bluff and the mouth of the Conway River, the Cretaceous rocks are again at sea-level, and abut against the older rocks to the westward, seemingly and presumably along a line of fault. Along the narrow valley of the Awatere River the Cretaceous rocks reach along it west from the sea a distance of fifty miles, and, although no such rocks appear in the Wairau Valley, they are yet to be met with at Picton, on Queen Charlotte Sound, deeply involved along a line of fault between Carboniferous or Devonian rocks to the east and metamorphic schists to the west.

In the western district of Nelson these rocks of Cretaceous age stretch along the eastern base of the Mount Arthur Range, and separated only from the Mount Arthur Range by the deep valley of the Upper Karamea River they cap the Merino Mountains at heights considerably more than 6,000 ft. above sea-level. In the same district rocks belonging to the same series are at sea-level in the Takaka, Aorere, and Heaphy Valleys, and towards Cape Farewell on Golden Bay and the west coast to beyond West Wanganui Inlet. In the southern part of the region north of the Rakaia and Hokitika Rivers, on the east side of the main water-divide, the Cretaceous rocks are found on the flanks of the outer mountains from the middle Waipara to the Malvern Hills, are deeply involved among the mountains surrounding the Trelissic Basin, within the Broken River watershed, and at Craigieburn, on the road from Canterbury to the west coast. In the Grey Valley and on both flanks of the Paparoa Mountains they appear at all levels up to 3,500 ft. above the sea, and in the lower and upper Buller watershed they are found at all elevations up to fully 3,000 ft., and where they appear in the valleys and lower grounds they usually abut against the mountain-ranges in such a manner as indicates the existence of a fault. Flexures are few, gigantic faults are traceable everywhere, and it is clear that the main orographic features of this part of the South Island have arisen since the deposit of the higher beds of this formation.

But this question naturally presents itself: When did the mountain-making process, chiefly by the rupture of the strata and the formation of great faults, have a beginning? Both on the east and west coasts of the south part of the region described, in the Marlborough District, and the Grey and Buller Valleys of the west district of Nelson, wherever remnants of Miocene strata are, these are involved with and in the same manner as the Cretaceous strata. Therefore the movements that resulted in the present state of things, as involving these Tertiary beds among the older rocks of what is now mainly a mountain region, began in Post-Miocene times, and ere the land had obtained great inequality of the surface the great Post-Miocene conglomerate of the Kaikoura Mountains had come into existence. This had been spread over the north-eastern part of the district long before the mountains that presently appear had reached their existing heights, or the great gravel-formation of the Moutere Hills and the "Old man" formation of the Grey Valley had been formed.

Within the north-east district of the South Island the survey carried on in 1885–86 and 1887–88 demonstrated the existence of three great lines of fault, and it was shown that at intervals these have been reopened during periods of earthquake disturbance, and that further displacements of the strata at such times have taken place. Reasoning on the effects, of which evidence is still traceable along the different lines of faulting, I came to the conclusion that earthquake displacements within comparatively recent times have resulted in the production of the mountains of Marlborough between the Wairau River and the sea-coast, and are responsible also for the varied features of the Amuri district of Nelson; but up to the date of the last report on the district there were no actual demonstrative proofs supporting the conclusions arrived at.

On the 1st September, 1888, New Zealand from end to end was startled by reports that an earthquake shock of extreme violence had affected the whole of the northern part of the South Island. Reports came from Christchurch, Greymouth, Westport, Reefton, Nelson, and Blenheim, all indicating that an earthquake shock of very great violence had taken place. In Christchurch part of the Cathedral spire was thrown down, and at the other places named, though the actual damage to buildings was not great, the force of the shock was alarming, the like not having been experienced in the South Island since 1855. Later in the day and the following day reports arrived from the Amuri district, indicating that in this part of the north-east district of the South Island the great shock had been far more severe than elsewhere. Over the Hanmer Plain, at

the upper end of the Waiau-ua Gorge, at St. Helen's, Jollie's Pass, the Hanmer Springs, and a number of stations along the northern border of the plain, the earthquake had destructive force, and at several places earth-rents were formed, which created considerable alarm. Buildings were more or less wrecked. The springs overflowed violently, and were otherwise affected as regards the clearness and quality of the medicinal and curative waters. The Press of the colony became excited, and reports appeared that afforded but little comfort to the inhabitants of the disturbed district. For the time being, the Hanmer Plain was considered the centre and seat of the most violent disturbance. Following the occurrence itself, it was speedily determined that this was an earthquake of such character as originates locally, and the epicentral point of the disturbance was fixed far away among the mountains of the north-west in a wild and uninhabited region where it could be a danger to no one. The facts, however, remained that a considerable amount of damage had been done, and that no little alarm existed over the Hanmer Plain and the district adjacent to the south and east. This earthquake series had been preceded, accompanied, and was followed by booming sounds in the earth, and these resembled the discharge of artillery at various but mostly considerable depths in the earth. These, after the passage of the great shock, did not tend to allay the fears and apprehensions of the inhabitants. Subsequently reports came from the Waiau-ua and Hope Valleys, west of the Hanmer Plain, which made evident that in that part of the district the force of the earthquakes had been of greater severity than experienced over the Hanmer Plain and the district to the east and south; and from these reports it became apparent that between Hopefield, at the junction of the Hope with the Waiau-ua, and Kiwi Creek, fifteen miles further up the Hope Valley, the greatest power of the earthquake had been manifested. Reports were circulated that a volcanic outburst was imminent in the neighbourhood of the Hanmer Springs, and the apprehension of such a *dénouement* created a veritable scare amongst the inhabitants of the district.

When these disturbances took place I was at Mahakipawa, in the Pelorus district, and while there received instructions to proceed to the Hanmer Plain and investigate and report the real state of affairs. I arrived at Jollie's Pass Hotel on the 5th October, four or five weeks after the occurrence of the great shock of the 1st September. Earthquake tremors had practically ceased, but the booming sounds in the earth still continued. I found the people about the hotel and in the neighbourhood still apprehensive as to what the meaning of these sounds might be, and nervously anxious to know my opinion respecting them. I had as yet no acquaintance with

these mysterious sounds, and so could only express the opinion that they were not indicative of dangerous conditions. This, however, did not allay the disquietude that prevailed, and I became anxious to experience the effects of one of these sounds. Nor had I long to wait. The same day while we sat at lunch a booming noise proceeded from the earth directly under the place where we sat. The whole company, except myself, sprang to their feet, and were outside the house as quickly as possible, exclaiming as they went, "Did you hear that?" Certainly I heard the sound; but there was no movement of the ground, and I considered there was no need for precipitate retreat or for alarm of any kind. And so it proved. No earth-tremor followed; and to me it seemed no more than might be experienced any day in a mining district when shots are fired off at noon or "crib" time.

From Jollie's Pass I visited most of the localities on the Hanmer Plain where the earthquake had left evidences of its power, and this work brought me eastward to the limit of visible disturbance on the Hanmer Pass and Hoosack Saddle. Beyond this to the eastward the effects of the earthquake were not traceable on the surface. Following the line of disturbance westward the visible effects increased till they culminated at Glenwye, in the Hope Valley.

The evidence collected on this occasion was embodied in a report to the Director of the New Zealand Geological Survey, and which, as the matter thereof has close bearing to the subject of the present report, I give here verbatim:—

NARRATIVE.

SIR,— Wellington, 22nd October, 1888.

In compliance with your directions I went from Blenheim to the Lower Awatere on the 29th September last, and thence followed the Awatere Valley to the source of that river. Crossing Barefells Pass I followed the Guide and Acheron Rivers to the junction of the latter with the Clarence. On the 5th October I reached Jollie's Pass and the Hanmer Hot Springs, on the 7th I went to St. Helen's Station, on the 8th to Leslie Hills, on the 9th to Glenwye, and on the 10th to the Upper Hope Valley. On the 11th I returned to Leslie Hills, and thence went to Waiau Township. On the 12th I went to the saddle between the west branch of Lottery Creek and the Hanmer River, and on the 13th by the Whale's Back and Cloudy Range Station to Green Hills; on the 14th to Kaikoura, and thence by the coast road to the mouth of the Clarence River. On the 15th I reached Flaxbourne Station, and on the 16th Picton, returning to Wellington on the 17th October.

REPORT.

From the crossing of the Awatere River (on the road from Blenheim to Flaxbourne) to Molesworth Station, near the source of the river, I made inquiries as to the effects of the late earthquakes, examined the old line of earthquake rent at various places, and ascertained that no damage what-

ever had resulted to buildings or other structures, and no fresh openings along the old rent or in any part of the Awatere Valley had been made—at all events, none have been observed.

By persons long resident in the Awatere Valley and Marlborough District the earthquakes of September last were considered as severe shocks, the heaviest of them exceeding any experienced in the district since 1855, although in violence falling far short of those experienced at that date.

It was not till reaching the junction of the Acheron with the Clarence River that any visible signs of recent earthquake action were to be noted. The accommodation-house at this place was slightly damaged, one side of the upper part of a chimney having fallen, lessening the height by some 2 ft.; and a small fissure in the shingle-bed at the junction of the Acheron was reported to me when I reached St. Helen's; but this I did not see, and heard nothing of it when I passed the locality.

The distance of the Clarence Accommodation-house from the line of greatest disturbance where it passes along the south side of the eastern part of the Hanmer Plain is some fourteen miles in a north-north-easterly direction, but at a right angle from the eastern prolongation of the line it is not more than ten miles; yet this is the most distant point at which any earth-fracture or damage to buildings has taken place. St. James's Station, at which damage was done by the earthquake of the 28th September, is about eight miles north of the line, and Leslie Hills Station about the same distance to the south of it. Lake Sumner is about six miles south of the earthquake fracture at the junction of Kiwi Creek with the Hope River, and the lower part of the Otira Gorge not more than ten miles south of the line as traced if continued westward.

Damage done at Christchurch and at Westport does not discredit the inferences to be drawn from these facts, because wide tracts of country interposed within which the earthquakes did little or no damage, and special reasons may be given accounting for the seemingly greater violence of the shocks experienced at those places.

At Jollie's Pass Hotel and at the Hanmer Hot Springs little or no injury to buildings was done, and, although at the springs, after the shocks of the 1st September, the wells emitted more gas, and, it may be, had for a few days a greater escaping volume of water, they very soon returned to their normal condition, and at the time of my visit were said to be slightly colder than usual. I examined the pool that overflowed, and that from which the cover was shifted during the commotions of the 1st September, and also that portion of the grounds which emitted jets of water and gas immediately subsequent to the great shock, and those that followed shortly afterwards; but of all this there was very little evidence left. A little mud on the grass-plot showed that the smaller well had overflowed to the south; but under any violent agitation of the ground this would not have been a surprising effect, as the water stood within 6 in. or 8 in. of the lip of the wooden frame over which it had to be and was discharged. The amount of mud or fine sand thrown out was not great, and I think could all be collected in an ordinary-sized galvanised-iron bucket.

The cover of the larger well had been replaced, and I could get no very clear account of the manner in which it had been shifted; but I understood that it had been thrown to the south or south-east of the well, and seemingly must have simply slipped off the frame on which it rested. This would tend to show, as the discharge from the lesser well also indicates, that the wave-motion was here emergent at quite a low

angle, implying the distant origination of the shock, or that the same originated along the line of fracture on the south side of the plain, at but a moderate depth from the surface.

With reference to the manner in which the springs and buildings may be affected by severe earthquake shocks occurring in the future, it is not easy to prognosticate; for, though it is true that both here and at Jollie's Pass Hotel but trifling damage has been done at this time, at Atkinson's station, as far distant from the line of disturbance, and at St. James's, double the distance of the baths from the line of weakness, the effects of the earthquakes have been of a far more violent character. But in this connection it must be noted that the earthquakes of the first week of September, though they may have been severely felt at St. James's, yet did no particular damage. It was the heavy shock of the night of the 28th September that threw down the chimneys and did other damage at that place. This and the series of lesser shocks which followed evidently had a similar origin to those of the 1st September, since at St. Helen's, at Leslie Hill, and at Glenwye the principal shock was regarded as second only to the great shock of the 1st September, and at St. Helen's was so severe as to induce Mr. Low to modify his plans for the restoration of the station-house, then being repaired.

It will scarcely be doubted that the two great shocks of the dates mentioned had their origin in the same or similar causes, and their first impulse from points not greatly removed from each other; but it is not easy to say why Atkinson's suffered in the first instance, and St. James's from the effects of the last shock, while the Hanmer Hot Springs and the northern edge of the plain to the foot of Jollie's Pass suffered so little.

The erratic, elective character of the earthquake, and its determining according to no known law where it shall or where it shall not do damage, leaves it a matter of complete uncertainty whether a given place or locality that may chance to escape the more violent effects of one or a whole series of earthquake shocks may not have a special visitation in which the localities previously shaken may or may not participate. In one word, the Hanmer Hot Springs have escaped this time, but no guarantee can be given that they shall not suffer equally with or more than Atkinson's or St. James's during future disturbances.

The only circumstance favouring the springs in comparison with some other places in the same district is that they are situate four miles to the north of the line of earthquake rent that extends along the base of the Looker-on Mountains, Cloudy Range, and Mount Sherwood to the Hanmer River, ten miles above its junction with the Waiau-ua, and thence goes west-south-west along the south side of the Hanmer Plain, and is continued along the Waiau-ua and Hope Valleys, and probably in that direction crosses the main range and water-parting of this part of the Island.

At St. Helen's and at Leslie Hills the damaged buildings had been partly repaired, or had been removed and replaced by new structures, so that I had not an opportunity of seeing them in the ruinous condition they appeared in immediately subsequent to the visitation which destroyed them partially or wholly.

At Leslie Hills, again, we have an instance of the selective character of the earthquake, or, what is more probable, the different resistant and responsive character of the soil and substrata on which different buildings may chance to be erected, or of the capacity of different classes of buildings to withstand shocks of the same force and intensity. The station-house was so far wrecked that the stone part of the building had

to be removed, in order to substitute a building of wood. The wooden part of the house as it originally stood was also severely damaged. But this was the only building on the place that suffered injury to any extent. The outbuildings sustained little or no damage, and at the men's cottage, less than a quarter of a mile to the north from the station-house (and in the direction whence the shock came), not only was no injury done to the building, but the men sleeping in it felt the shock or series of shocks so little that they had no idea of the serious consequences experienced at the dwellinghouse, and knew nothing of what had happened there till the hour of commencing the duties of the following day, when they were sharply upbraided by Mr. Rutherford for their little concern as to the welfare of the family in the station-house. Mr. Rutherford's complaint was met by the reply that they did not consider the matter of such serious moment, and never dreamt that such wreck and ruin had been caused so near at hand, or that inconvenience and danger had been experienced so close to where none of these things had happened.

Of the ground-rents said to have opened along the bed of the Percival River, these appear for the most part to have closed or been filled by the falling-in of the sides, though Mr. Low, of St. Helen's, informed me that he could still find one special rent open which was said to be nearly 10 in. in width. This, however, I did not see, and in riding along the plain to the junction of the Hanmer with the Waiau-ua I saw no fissures nor rents of any kind.

On the 8th October, as my instructions directed, I went to Leslie Hills Station, where I saw Mr. Rutherford, and together we went to Glenwye Station the following day. On our way through the Waiau-ua Gorge Mr. Rutherford pointed out two slips on the east side of the gorge, and stated that these had been caused by the earthquakes of the 1st September. These, though of considerable extent, were simply slips of the surface and subsoil on the north side of the eastern range of the Leslie Hills. True fissures might be attendant, but they have not been observed.

At the bridge at the upper end of the gorge there were no visible signs of an earthquake having occurred; but I was told that some rocks had fallen on the Leslie Hills side of the river. The hotel close to the bridge was violently shaken, though without any serious injury to the building itself: the contents suffered severely.

In following up the south bank of the Waiau-ua not a trace of the effects of the earthquake was observed for the first four miles west of the upper end of the gorge. At this distance, however, the track passes over a spur of the range on the south side of the plain, which, terminating in an abrupt cliff, has its base washed by a large stream of the river. On the western face of the spur earth-rents that, when formed, might have been 4 in. or 5 in. wide crossed the track in a westerly direction. One or two of these appeared to be true rents, and were they more numerous than they are the stability of the spur between the horse-track and the river might be endangered. The track crosses at 250 ft. above the river-bed.

After gaining the low ground slips of the talus-slope at the foot of the cliffs were plentiful. These somewhat resembled true rents; but I judged of them, nevertheless, that they were superficial, or comparatively so. The horse-track here rejoins the dray-road, which, further down (to avoid the high bluff), had to follow the river-bed, and it now, by a long cutting, rises to the higher level of McIntosh's Flat.

Crossing an old line of earthquake rent the road was continued west a

Fault-line and Earthquake Rent, Jones's Flat, Waiau-ua Valley; reopened September, 1888.

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little to the south of this. This old rent, in a very marked manner, divides the terrace-flat into two parts—a north and a south part—and runs nearly east and west, parallel to the general course of the Waiau-ua River and valley. Since its formation it has been widened and deepened, especially the eastern part, by the drainage of its own area and by becoming the channel of a small stream coming from the south. Towards the west end of the flat it is in much the same condition as when first formed.

The late earthquakes have again formed fissures along this line, and fissures and slips begin to appear on the sides of the high terraces forming the south side of the valley and lower slopes of the ranges in that direction.

At Jones's station the old earthquake rent passed on to a terrace of lower level, and we had less opportunity for observing it closely; but shortly it regained the same level as the road on a further continuation of McIntosh's Flat, or a river-terrace at the same level, and now along the road there were everywhere abundant evidences of the earth-shakings that had taken place.

All the cuttings into and out of the different creeks crossed by the road had been rendered difficult to pass or impassable; but a road-party was at the time engaged in making repairs, and thus far the road was quite passable.

Before reaching the crossing of the Waiau-ua to Hopefield Station the long cutting descending to the river-bed had been rendered almost impassable to horsemen, but was being made good as speedily as possible. Rents were everywhere on this cutting, some of them being more than 12 in. wide, and these, with the slipped outer edge of the road and fallen banks from the upper side, showed clearly what the violence and force of the earthquake had been.

Half a mile below the mouth of Gorge Creek the horse-track along the south bank of the river the earthquakes had rendered impassable, and to avoid this the river had to be crossed and recrossed above Hopefield to regain the horse-track near to where it joined the wagon-road leading to Glenwye. At all times the dray traffic followed this course; but to avoid crossing the river when high the horse-track had been cut along the southern bank. This I attempted to follow on foot, but found I had undertaken a task beyond my ability to accomplish. Such was its wrecked and ruined condition that at places it could not be distinguished that a track ever existed, even where it had been cut into the solid rock. Especially on both sides of Gorge Creek was this wreckage of the track complete; but the fissures and dislocations did not extend far back from the brink of the river-cliff, and the middle part of the belt of disturbance appears to have been the river-bed at this place. No pen, and scarce the most graphic touches of an accomplished artist, could give a just and complete rendering of the river-bank and edge of the terrace (shingle above and rock below) at this place. Photography properly directed might do something.

The fissures and rents formed in the shingle of the river-bed have since the occurrence of the earthquakes been overswept or closed up by freshets; but some rents are seen in the grass-paddocks on the Hopefield side of the river, and Mr. Rutherford described to me a small area which had sunk about a foot below the general surface of the ground. This was close to Hopefield Station-house, and the alarm and flight of the inmates on the morning of the 1st September will thus appear to have been not wholly without cause.

On the dray-road crossing from Hopefield to the south bank of the river, just below the junction of the Hope, flowing east, with the Waiau-ua, coming from the north, the road, going to Glenwye, crosses the broad low-sloping fan of Shingle Creek, and on this rents and openings 4 in. to 6 in. in width began to appear, and became more numerous as we proceeded westward. These were true fissures on a flat surface, unlike many that appeared on the edges of the terraces, where the ground-rent was not equally supported on both sides.

Beyond Shingle Creek the road follows the northern lower slope of a ridge of hills to Horse-shoe Lake, and this we found rent at many places, and generally encumbered by fallen stones from the heights above.

About half a mile east of Horse-shoe Lake a cubical mass of rock some 6 ft. square encumbers the road. Seemingly it has fallen or rolled down from the heights above, but it has left no track in its passage to the lower grounds; and after vainly trying to determine whence it had come we had to give the matter up. Another of equal size, a quarter of a mile further along the road, had been shot out of the bank below the roadway and lodged in the swamp at the foot of the slope. This had evidently been burst asunder at the time of its displacement, as the larger fragments, three in number, had taken different courses, and yet, strangely enough, had come together again at the end of the journey. That this mass of rock as it lay *in situ* in the bank, before being subjected to the shock that discharged it thence, was sound and solid was evident from the freshly formed fracture-faces that had been made; and a part only of the boulder was hurled from its place, as two or three smaller fragments remained in the original bed which the whole had occupied.

The swamp mentioned is an old channel of the Hope River, and Horse-shoe Lake is a part of the same, the waters of which are held back by a landslip from the ridge of hills to the north, between the lake and swamp on the one hand and the present channel of the Hope River on the other. This ridge of hills is covered with rents and slips, and towards the west, where its southern slope retains Horse-shoe Lake, and at its western termination, where it slopes to the level of Kakapo Brook, it is a complete wreck—so much so on the slope towards the lake that a great part of it threatens to be precipitated into the waters below, repeating the process by which the lake was formed, but with a different effect—viz., the carrying-away of the road and the partial filling-up of the lake. On the northern side of this ridge of hills a very large slip has already taken place in the direction of the Hope River. The opposite western bank of Kakapo Brook is also badly shaken, and the road leading up this on to the station-flat is almost obliterated.

Glenwye Station-buildings have been erected on a terrace of the Hope River, somewhat more than 100 ft. above its present channel. The eastern end of this terrace is washed by Kakapo Brook, the northern side by the river, while the south side and the western end have their limits along a curved line, the segment of a circle the centre of which might be placed near the junction of Kakapo Brook with the Hope River. The greatest length of the terrace-flat, east and west, is about half a mile, and the greatest breadth somewhat less. The station-buildings stand at the eastern extremity, under the higher terrace to the south, and comprise the manager's cottage, men's cottage, woolshed, store, stable, and workshop. The sheep-dip and tanks for preparing the dip-mixture may also be spoken of as an erection. The two dwellinghouses and the store stood nearly in a line parallel to and nearest the old earthquake rent,

which runs west between the southern margin of the lower flat and the top of the high terrace to the south and west. The woolshed stands a few chains to the north, and the stable and workshop the furthest west of all the buildings, in an intermediate line, the eastern end of which would be occupied by the dip.

The great shock of the series of earthquakes occurring on the morning of the 1st September effected the greater part of the injury done to the buildings, though under the influence of other and following shocks they may have suffered further damage. The stable, workshop, and storehouse were not much injured. The men's cottage is a total wreck inside, and, although the walls have not departed greatly from the vertical, the whole building has been shifted from the piles on which it stood, and is now some 15 in. more to the north than it was before the earthquakes. The manager's cottage has suffered equally, but has not been displaced from its foundation. It seems to have been screwed and twisted in all possible directions, and finally has settled down with a considerable list to the eastward.

Very different is the appearance of the woolshed. This is a large building more than 100 ft. in length, and between 40 ft. and 50 ft. in width, and in its ruined condition presents a rather melancholy appearance. It is broken-backed in two places, and the side walls are erratically sinuous, although nowhere actually ruptured. The piles on which the building stands are partly drawn from the ground, and lean to the east 30° beyond the plumb-line (the building stood with length north and south), and the whole building leans also in this direction. It is just a question whether it can be jacked up, the piles replaced, and with some repairs made good, or whether the whole superstructure will have to be pulled down. An attempt at restoration is to be made.

The sheep-dip was not damaged to the extent at first reported. The mixing-tanks and their setting are, however, a complete wreck. The tanks set over the furnaces had a capacity of 400 gallons each. These, of course, were partly imbedded in the masonry, and at the time of the earthquakes were full of water. Thus weighted they appear to have been pitched into the air, and the whole of the masonry in which they were set so wrecked that no two bricks cohere or are in their places. This masonry was of a substantial character, the bricks, &c., being laid in Portland cement of supposed best quality, and the work had been executed long enough to allow the cement to mature. The condition of the dripping-floor showed this. The tanks now rest on the upper surface of a confused heap of bricks and mortar, their side angles and corners partly imbedded in this.

There are but few rents on this lower or station flat, and those only at its southern edge, close under the high terrace. One large rent, running north and south, crosses the dripping-floor of the dip; but this has been caused by the rigidity of the cement floor not yielding to the earth-wave that passed from west to east along the station-flat, and which was of a height sufficient to draw the rails of the enclosing fence 3 in., and free them from the mortises into which they were fitted.

Close to the buildings most of the rents run along the steep slope between the upper and lower terraces. The higher terrace is 350 ft. above the station-flat, or nearly 500 ft. above the river at the junction of Kakapo Brook. It forms a high terrace-flat, a mile to a mile and a half in width north and south, and quite four miles in length, west from Glenwye, beyond which distance it is considerably narrowed, a mile below the junction of the Boyle with the Hope River.

An old line of dislocation caused by former earthquakes runs along the middle of this higher terrace, and the recently formed earth-rents follow the same course, or nearly so. At the back of Glenwye Station the recently formed fractures are on the face and brow of the high terrace, and a little to the west on the upper flat itself, where over nearly a quarter of a mile the whole surface is a network of fractures, fissures, slips, and dislocations. At one place an area of about 4 chains in width and 10 chains or more in length has subsided 2 ft., as indicated at the fractures, and the middle part of this may have subsided even more than that.

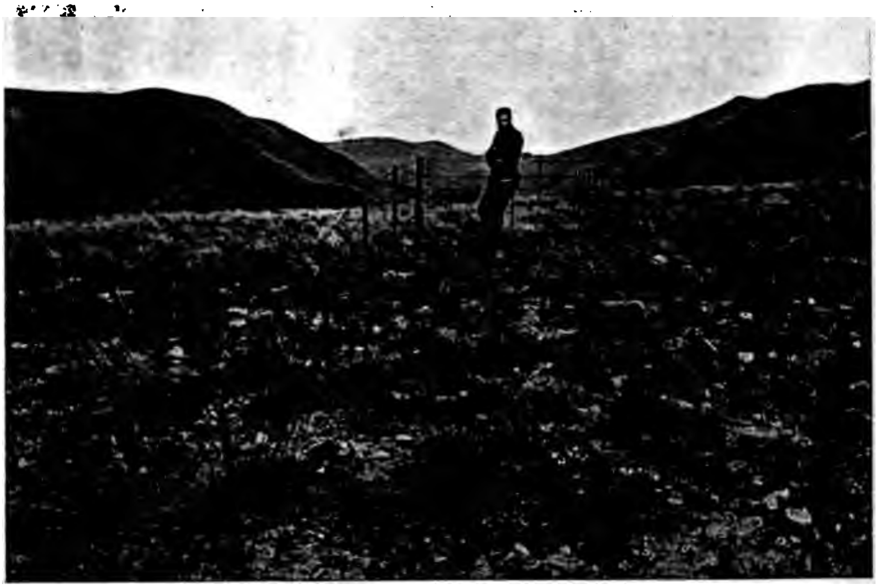
From Glenwye Station a wire fence runs up the sloping face of the terrace to the flat above, and this on the face of the terrace was originally in a straight line, but the great shock displaced the lower part of the terrace-slope to the east, and at the same time the fence, though not actually sundered by a sudden displacement, was shifted 5 ft. out of the true line. Many of the iron standards were drawn from the ground, and the whole or most of this part of the fence will have to be lifted.

About a mile and a half beyond Glenwye the fence of the west side of the larger station-paddock crosses the old earthquake rent, and just on the very line the fence has been sundered and thrown to the east a distance of 8 ft. 6 in. This involves movement to this amount along the earthquake-line of the whole of the northern half of the terrace. About a quarter of a mile to the north of the dislocation the western corner of the north side of the paddock is reached, and no fence is continued in the direction of the river. Here, then, were the last means for determining at what rate the displacement died away in the north direction; and I here found that the corner-post of the fence was 5 ft. or 6 ft. east of the line of the undisturbed part of the fence south of the earthquake fissure. Probably the Hope River would have to be passed before reaching ground that had not been shifted to some extent.

Less than a mile and a half further west another fence crosses the terrace-flat in like manner, and this where it crosses the earthquake rent has been broken, and shifted to the east 8 ft. also. No north-and-south fractures that would indicate the east-and-west limits of this displacement could be detected, and, as at the furthest west fence on the high terrace-flat the amount of shifting was 8 ft., and at Glenwye Station 5 ft., the movement cannot have begun and ended at these places. The displacement of the country to the north of the line of old fracture therefore probably extends from Hopefield Station, at the junction of the Hope and Clarence, to the junction of the Boyle with the Hope, a distance of eight miles; but at what distance to the north of the line the displacement becomes nil has not been determined, but, as already pointed out, this point is probably no great distance beyond the Hope River.

At each end of the tract of country thus displaced the old earthquake fissure and line of present disturbance is, or is nearly, coincident with the present channels of the Waiau-ua and Hope Rivers, and at such places the evidences of this movement were necessarily of a temporary character, leaving no marks whereby the amount of lateral thrust of the country north of the line can be ascertained.

In the Hope Valley, above the junction of the Boyle River, the rents and fissures begin to be less abundant than they are in the vicinity of Glenwye, and they are somewhat different in character, being now for the most part confined to the sloping faces of the terraces sinking from one level to another, and to the paring and shaving-off of the overhang-



Fault-line and Earthquake Rent, Glenwye, showing Horizontal Displacement of 9 ft. by Earthquakes of September, 1888.

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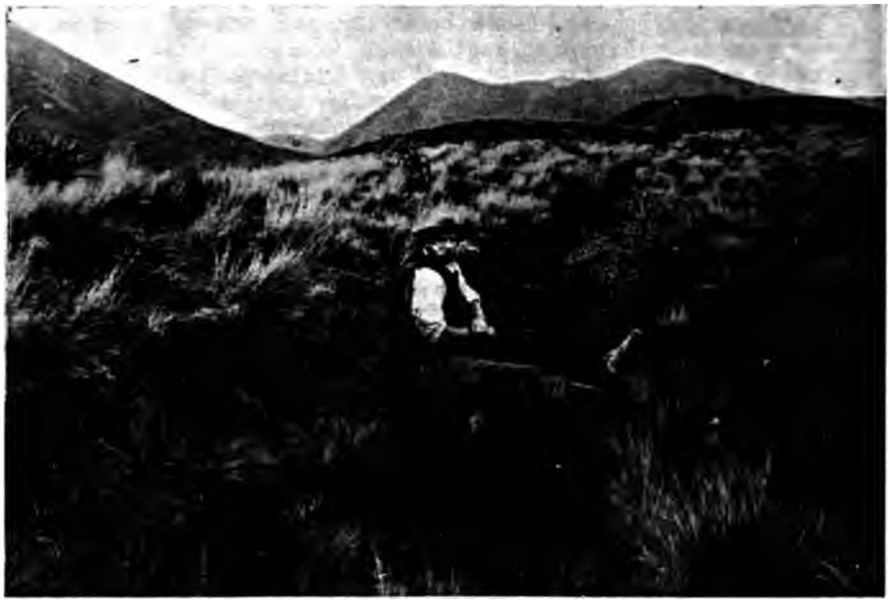

Fault-line and Earthquake Rent, Glenwye; reopened September, 1888. [To face p. 28.

ing eaves of shingle and creek banks. These are not true rendings, but more the result of excessive vibration and shaking of the surface. The middle part of the Hope Valley has a width of less than a mile, and on each side of it the mountains rise abruptly to between 5,000 ft. and 6,000 ft. above the sea. The low ground along the river is about 1,600 ft. above the sea. On the north side of the valley the mountains are bush-clad, and on the south side grassed or bare rock to the summit or the snow-line of spring and early summer. The mountains on both sides are marked by a great number of landslips that have taken place recently, and these were not observed previous to the beginning of September last, and all are agreed that, as they appear to be, they are due to and were formed at the time of the late earthquakes.

The Hope River turns to the north and leaves the main valley at the point where it is joined by Kiwi Creek, which, draining the adjacent mountains, runs along a low valley by which Lake Sumner, six miles from the Hope junction, may be reached without passing over any high ground. In fact, it seems most probable that the upper Hope at one time flowed into Lake Sumner, and was therefore one of the sources of the Hurunui River. The main valley of the Waiau-ua and Hope River is continued west as a depression among the mountains; but two miles beyond the junction of the Kiwi with the Hope the waters flow either along some of the sources of the Hurunui or to the west coast, a low saddle here forming the water-parting. But the remarkable depression which to the east opens out to form the Hanmer Plain is continued west in the same line, and no mountain interrupts the view along this depression which may be had from the high terraces of the Hope Valley, which are nearly as high as the saddle itself. This is the line of continuation of the old earthquake rent and recent fractures.

Where the Hope River turns to the north, for a quarter of a mile its waters are confined and contained by a deep rocky gorge, the hill-slopes on either side of which are bush-clad. Above the gorge the valley widens, and the river flows along a wide shingle-bed, with grass flats on either side, to the edge of the bush and lower slopes of the ranges.

A mile below the junction of the Kiwi we crossed from the south to the north side of the middle Hope Valley, and skirted the edge of the bush on that side, noting that very many of the dry birch-trees in the bush had been broken and thrown down by the earthquakes, and that these were generally broken off 10 ft. to 15 ft. from the ground, the timber, though dry, being sound for the most part, and the roots holding firm in the ground. Some of the trees thus broken were at least 1 ft. in diameter, and some I should estimate were larger than that.

In many cases the dry timber falling had carried away branches of green trees; but in more than one instance it was noticed that large branches were wrenched from living trees where no dry timber had fallen, and where such was absent. High winds, however, may have done this,* but the belief is that this also was the work of the earthquakes, and probably it was so. In other cases green trees 25 ft. to 30 ft. in height have been torn up by the roots and are now in a prostrate position. This has happened both on shingly and on rocky soil.

In passing through the bush to gain the upper valley of the Hope, a tree 30 ft. in length and 12 in. to 15 in. in diameter was thrown across the

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* Indeed, all the fallen timber might be considered due to the winds. The man staying in Jones's hut reported the broken timber as due to the earthquake; and this being confined to the vicinity of the fracture-line lends colour to the assumption.

track, and had to be cleared away before we could proceed on our journey. This tree had powerful roots, which had been firmly fixed in the fractures and irregularities of the rocky bank on which it grew. Excessive and sharp must the vibrations have been that wrenched it from the position in which it stood; yet this tree, it was presumed, had been overset by the earthquake, and its having fallen was known to Mr. Thompson, manager of Glenwye Station, who accompanied us provided with an axe.

We proceeded along the Upper Hope Valley to Jones's hut, which was reported to have been wrecked by the earthquakes of the 1st September, and which report had it that a fissure had opened and again closed with such violence that a ridge of some height was thus formed and was traceable for a mile along the river-flat.

Before reaching the hut most of the signs of earthquake action had died away. There was little fallen timber in the bush, no freshly made slips on the mountain-sides, and no earth-fractures on the flats by the river-side, nor even the eave-like projections of the river-banks were shaken down, and we were now certainly beyond (to the north of) the line and belt of country most violently affected by the earthquakes. Of the closed fissure and the raised mound one mile in length we could see no trace; and, indeed, but for the statement that such existed I should not have expected its occurrence. Jones's hut showed no signs of having suffered from the extreme violence of the earthquake shocks said to have damaged it, and the statement that the one inmate of the building on the night of the 31st August and the morning of the 1st September was blocked therein and had to cut his way out seemed to have no foundation in fact. On careful examination of the hut we came to the conclusion that probably the door got jammed in the frame of the door-posts and lintel, and might have required a little trouble to set it open. Nothing of a more serious nature could have happened.

Passing thus beyond the region visibly bearing traces of earthquake action, we did not deem it necessary to proceed further in the direction of the Hope Saddle, and from the hut we returned to the junction of the Kiwi Creek with the Hope. We might have followed the earth-fractures, old and new, about a mile farther, to the edge of the bush on the east side of the low saddle already mentioned; but the day was passing, and it was necessary to return to Glenwye before dark, the condition of the track making this imperative, unless we chose to remain in the bush for the night. So we contented ourselves by noting what further might be seen from this the furthest point along the line of disturbance to which we reached.

The mountain-range lying between the low saddle mentioned and the source of the Hope River and Hope Saddle had on its eastern spur one notably large slip and some of lesser size. The large slip looked to me as though it had been there before the earthquakes; but Mr. Rutherford, not having noted it previously, was of opinion that it not only was caused by the earthquakes, but also that it appeared right in the line of greater dislocation which we had followed more or less closely from Glenwye. No such slips could be seen in the valley of the Boyle River, and Mr. Thompson told me that a traveller from the West Coast, coming by way of Cannibal Gorge and the Lewis and Boyle Rivers, had noticed not the least signs of earthquake action till entering the valley of the Hope. Thus, so far as surface indications may be taken to locate the centre from which the initiative or shock of greatest force spread in all directions, this cannot be placed in the vicinity of Cannibal Gorge, neither near Lake Christabel, nor to the north-east of Amuri Pass.

The facts which I noted, in my opinion, tend to show that the great shock of the morning of the 1st September commenced at some point to the west of Glenwye, perhaps further west than the junction of the Kiwi with the Hope, and that it travelled eastward with increasing force to Glenwye and Hopefield, beyond which places, by what appears at the surface, its destructive character began to be less; and, although as far as the eastern end of the Hanmer Plain its violence was great, if rents and fissures are to be taken as a measure of its force, it was here mild and tame compared with what it was at Hopefield and Glenwye.

Though the earthquake did much damage at St. Helen's, at the east end of the Hanmer Plain, at Atkinson's, on the north side, and at Leslie Hills, eight miles south of the line of fracture, and though a number of small rents were formed along the bed of the Percival River, clearly in this direction the power of the movement and force of the shock was being rapidly lessened; and not more than ten miles further to the east, between the Hanmer River and Lottery Creek, there is not the least indication of fresh disturbance along the old line of earthquake rent.

The great fault and old earthquake rent of the middle Clarence, if continued from the Gore River in the same line, would cross the east-and-west line lately in movement at St. Helen's, and the Waiau-ua River at Marble Point, and to sympathetic action along part of this line may be attributed the locally increased effects experienced at St. Helen's and Leslie Hills Stations. The greater violence of the shake at Atkinson's station than at the Hanmer Hot Springs or Jollie's Pass Hotel was probably due to another cause.

Mr. Thompson, of Glenwye, informed me that the shocks following those of the morning of the 1st September caused the buildings to vibrate with extreme rapidity in an east-and-west direction, and that, though he cannot say that the great shock came from the west to Glenwye, it certainly passed down the valley eastward from that place at a measurable rate, and was accompanied by a terrific roaring noise, which died away in the distance, while things were momently quiet at the place where he stood.

From the Hanmer Plain I followed the line of disturbance to the eastern base of Mount Fyffe, near Kaikoura, where the last damaging effects of the earthquakes took place. These were not very noteworthy, only one or two chimney-tops having been injured on the Kohai Flat, and there were a few fallen rocks in the bed of the Charwell River, near Green Hills.

While at the Hanmer Plain I had an opportunity of judging of the nature of the booming noises which have been heard in the Amuri district for the past twelve months. The first I heard was at St. Helen's, on the 6th October, and this dull and indistinct sound resembled the rumble of a distant avalanche, but no two persons could agree as to the direction whence the sound came. The second I heard the same day at Jollie's Pass Hotel. This resembled a strong blasting-shot in a mine, as heard from another and distant part of the mine. The first was accompanied by a slight shock of earthquake; to the last no shock succeeded. At Glenwye the general opinion was that these noises came to them from the north, at Leslie Hills from the west, and at St. Helen's from the north. These booming sounds have been heard as far to the east as Green Hills, eighteen miles south-west of Kaikoura, and there they appeared to come from the north-west.

The above notes embrace most of the observed facts that came under my own notice during my recent trip to the Amuri district, and I have

added a few facts observed by others. My further report will contain information from a variety of sources more or less trustworthy. And there is a mass of information already on record, printed and in manuscript, which in the light of recent events will require restatement before the more proximate primary causes of these disturbances can be indicated, or the immediate and moving causes pointed out; also, the effects which like disturbances have produced in the past, altering the former configuration of the country and determining that of the present time.

I have, &c.,

The Director, Geological Survey. ALEX. MCKAY.

POSTSCRIPT.

During the progress of my examinations detailed above I was often asked if it was my opinion that the late disturbances would eventuate in volcanic action, and when I answered "No" the queriest usually wore a disappointed look, and seemed to regret that his forebodings would not be realised.

The opinion has been hazarded that these Amuri earthquakes are the premonitory symptoms of a coming volcanic outburst; and to the inhabitants less informed on such matters it appears unreasonable that such should not be the *dénouement* of the mysterious noises and earthquakes that have taken place. Therefore, lest the foregoing account should be considered incomplete, I shall take this opportunity of indicating, as shortly as may be, what actually took place, how and where the rupture began, and what is likely to eventuate before the earthquakes cease and the next period of repose is entered upon.

To say that there shall be no volcano might prove to be a rash and unwarranted assertion; but I shall be justified in stating that such an eventuality is highly improbable. No volcanic action has taken place in any part of the north-east district of the South Island since early Miocene times. Then, and backwards through time till about the middle of the Cretaceous period, volcanic action was rampant in the Marlborough and Amuri districts. But this died out before the close of the Miocene period, and, after a time of quiescence ending with the older Pliocene, the present phase was entered upon, which is that of the Earthquake, distinguished from mere explosive shocks (however violent locally) in the neighbourhood of volcanic action.

What the Earthquake has effected since the middle of the Pliocene period to the present day I shall take another opportunity of describing in detail; but in what it has not done lies the answer to those who anticipate volcanic action as the result of the earthquakes of the past two months. While it has rent and torn an undulating country or plain of vast extent, upheaving the fragments into mountain-masses that now pass the limits of perpetual snow, it has effected this work without the slightest induration of the strata along the friction-lines. The force acting had its expression in motion and the elevation of the country, not in motion resisted and the production of heat.

It is common to speak of earthquake shocks as originating at a point or centre whence the effects radiate upwards and outwards, the point of impulsion being at a considerable depth in the earth. The emergent waves thus produced, their times and their angles, are thus made to indicate the starting-point by various means; but all of these modes of estimation appear to rest on the assumption that for a particular impulsive shock the centre is a fixed point, to indicate which at the surface,

and its depth below the surface, gives the key to the whole complication of effects that follow.

But this is not necessarily the case; and if the assumption of a distinct centre is to be adhered to, then it follows that what may be called the "great shock" of the 1st September consisted of a great number of independent minor shocks, having lineality and coincidence as regards place with a line that had been affected in the same manner previously. These minor shocks were so nearly coincident in time that, if the effects they produced had any measurable duration, these, however expressed, must have overlapped, and, unless the transmitting media were of extreme uniformity (which we know was not the case), individuality of these effects would be lost, and the result would be one vast quavering, which, at the surface, could not be referable to one point, but to a large part of the line affected. The main action along the line of weakness would, as a consequence of the supposition that there was no true and absolute centre for the whole disturbance, assume the character of rending or crushing along a line; and that this was the true character of the earthquake the natural seismographic record at the surface appears to indicate.

The lateral displacement of the country along the north side of the old earthquake rent, according to this hypothesis, seems capable of an explanation, since the tension-strain was relieved horizontally, and, so far as I can see, the vertical movement had already taken place, or has yet to take place, in which latter case equilibrium has not been restored, and the earthquakes are not yet at an end. ALEX. McKAY.

COPY of TELEGRAM from Mr. D. RUTHERFORD to Mr. A. McKAY, dated Culverden, 29th October, 1888.

EARTHQUAKE shock on Tuesday, the 23rd instant, at 8.17 p.m., direction west to east, with loud rumbling noise and undulating motion. On Friday, 26th, at 12.48 a.m., similar shock to that of Tuesday, but lasting longer, with undulating motion. On Sunday, the 28th, at 7.22 a.m., a sharp, jerky shock, no noise, direction west to east, lasting only two or three seconds. The general opinion is that the first two shocks did not originate at Hanmer Plains.*

The examinations above detailed led to the conclusion that at the southern base of Mount Sherwood the line of fault and fracture running along the east base of the Looker-on Mountains, Mount Clear, and the Cloudy Range altered its course, and thence ran nearly east and west across the Hanmer Pass along the Hanmer Plain, the Waiau-ua and Hope Valleys to Kiwi Creek, this latter point being as far as the earth-fracture was traced on that occasion.

The district east of the Mason River to the sea between the mouth of the Conway and Goose Bay had not then been examined with respect to the east continuation of the line of rupture traceable from Kiwi Creek to Lottery Creek, a western tributary of the Mason, and, as I could not trace the Kaikoura fault south-west along the lower slopes of the Leslie Hills and the west border of the Hurunui–Waiau

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* This is probable. The shocks appear to have been felt at Kaikoura more strongly than elsewhere, showing that the old fracture-line is being opened afresh in that direction.—A. McKAY.

Plain, I concluded that from the point mentioned it altered its course and trended more to the west, and took the line of the earthquake rent reopened by the disturbances of 1888. But, however this matter might have been misapprehended, the examinations subsequent to the earthquakes of 1888, and the report thereon, above cited, proved conclusively that the great fault-lines traversing the Marlborough Provincial District are still subject to further opening and displacement by earthquake agency.

The earthquakes commencing on the 16th November last, as reported from the Cheviot district, led to the impression that not the east and west line along the Hope and Waiau-ua Valleys and the Hanmer Plain was being reopened, but the line of the south continuation of the Great Clarence fault, the shocks being reported as coming from the west, and I was under that impression till the time I arrived at Cheviot. But a short investigation convinced me that the earthquakes did not originate to the west, but to the north-west and north of the Town of Mackenzie and other parts of the Cheviot Estate. The displacement of the buildings in almost all cases conclusively proved this, and the greatest severity of the first great and succeeding shocks was seen to be along a belt of country flanking the west lower slopes of the coast range, which, continued to the north, runs along the valley of the Leader River and the west slopes of the Hawkswood Range.

The whole of Cheviot County felt the great shock severely, and over the east and middle parts of the estate, as far to the west as the flanks and higher slopes of the Lowry Peaks Range, houses having walls and interior divisions of brick, sun-dried brick, or cob were more or less ruined and thrown down. North of the Waiau-ua the greatest force of the earthquake seems to have been at Mendip Hills Station, on the west side of the belt of country referred to; but opposite Mendip Hills Station, on the east side of the continuation of the old Secondary or Palæozoic rock that, forming the Lowry Peaks, is continued north of the Waiau-ua, in Mount Parnassus, and the hills between the Stanton and the Leader Valleys, the force of the earthquake was much less.

In the Mason Valley the force of the principal shock, though great, was less than farther to the east in the Stanton and Leader Valleys, and over this part of the district all the evidence obtained points to a more directly north-and-south direction of the shock. The evidence thus far led to the assumption that not the Great Clarence fault-line had been chiefly affected, but a continuation west of the line reopened by the earthquakes of 1888. This, continued in the line of the western observed part from the upper part of Lottery Creek, as already stated, should pass between Mount

Cookson and the Whale's Back, and, crossing the Conway above the junction of the Spey, reach the coast-line at Goose Bay, a few miles north of Amuri Bluff. Along and south of this line it is reported the earthquakes occurring on and since the 16th November were felt with perhaps greater severity than elsewhere, Mendip and Parnassus not excepted.

While to the south of this line the earthquakes were felt with great severity into northern Canterbury, even to Amberley, Kaiapoi, and Christchurch, to the north of it the force of the great and succeeding shocks rapidly diminished, and at a distance of six or eight miles the damage done was exceedingly trifling. Neither at Kaikoura nor Green Hills was the force of the great shock alarming, and this also was a characteristic of the earthquakes of 1888 along the Waiau-ua and Hope Valleys, little damage being done six or eight miles north of the line of fracture, except at St. James's Station, where the greater violence experienced was due to the station-buildings being situated on the line of the Awatere fault, which, crossing the Hope Valley at Glenwye, would also account for the extreme violence of the great shock at that place.

The Hanmer Plain, Waiau-ua and Hope Valleys felt the shock of the 16th November last but slightly, or as a moderate shock only. East of the Leslie Hills its force increased as it passed over the Mason Valley, Mount Cookson, and Mendip Hills, in the direction of the mouth of the Conway. The earthquake of 1888 originated in the west, but whether east or west of the main range cannot be determined. Suffice it to say, it came to Glenwye from the upper part of the Hope Valley; and on the authority of the manager at Glenwye (Mr. Thompson) the shocks succeeding the great shock caused buildings to vibrate with extreme rapidity in an east-and-west direction, and, though he could not say that the great shock of the 1st September, 1888, came from the west to Glenwye, from there it passed to the eastward, along the lower Hope Valley, at a measurable rate, accompanied by a terrific roaring noise that died away in the distance, while things were momently quiet at the place where he stood. (See report on the earthquakes of September, 1888, quoted above.)

In the case of the recent earthquakes forming the subject of this report, in the Waiau district, from the testimony of residents they appear also to have begun in the west of the district affected, and as the great shock travelled east its violence seems to have increased.

Mr. G. H. W. McClure, Government surveyor, at the time of the great shock of the 16th November last, stated in my presence that he was in the field and on Lyndon Run near the spot where the line of fracture passes from the Hanmer Plain to the Mason Valley, and at

reported to me as far as the period between the 16th and the 22nd November is concerned, and subsequent to the latter date I had opportunity of observing the fact for myself. Usually the nor'-wester lulled about sundown, but sometimes the wind continued strong through the night, except just before and after the occurrence of an earthquake shock. On more than one occasion it was remarked to me that we were about to have another shock, because the wind had gone down, and a sort of unnatural calm prevailed. Without fail the shock, light or heavy, would come, and shortly after the wind would start afresh. This was at Cheviot. The same story is told at Waiau, and wherever I have made inquiries respecting this matter.

How far the accumulating strain to be released by the earthquake shock affected the atmosphere and produced a state of calm, or how far the earthquake itself was due to atmospheric causes, may not be easily determined, and these coincidences have also to be considered in connection with the sub-aerial noises near the surface and at greater depths in the earth. These also have some connection with the state of the atmosphere. Their history is interesting. They occur over the whole of the Amuri district and some parts of Marlborough, and at times considerably before or after the occurrence of earthquake shocks, but are more abundant or are more noticed at such times. They are frequent during the winter season, when snow lies heavily on the ground, and are common at all seasons. For a twelvemonth prior to the earthquakes of September, 1888, they had been more than ordinarily frequent, and for some time previous to those of November, 1901, they had been specially noticed in the district north of the Conway, east of the Whale's Back. In part in some way they are resultant from the stress that produces the earthquake, but at the same time their dependence on the state of the atmosphere is very evident. My information, so far, leads to the conclusion that these sounds are more frequent along the principal lines of ascertained faults, but they are by no means confined to such locations. They are of two kinds, such as affect the surface of the ground and the lower strata of the atmosphere, and those that affect greater depth in the earth. The first is distinguished by a sharp rattling sound; the last is ushered in by a dull thud, which ends in or is followed by a low booming sound.

It were useless to dogmatize on the cause and the connection of these sounds with further displacement along lines of faults in the district over which they occur, or their connection with earthquakes when these latter do take place. Too little is known about them, and the uncertainty of the time and place of their occurrence

makes the study of them difficult. I have already mentioned the occurrence of the deeper-seated booming variety as experienced at Jollie's Hotel on the 5th October, 1888. I experienced the same variety at Cheviot on the night of the 1st December, 1901. This latter immediately followed a very heavy shock of earthquake, and the explosion, if such it was, was some distance to the north of where I then was, or in the direction whence came the shock of earthquake immediately preceding the booming sound.

On Highfield Station, near Waiau Township, on the morning of the 9th December an explosion of the more superficial kind took place. This I did not hear nor see the immediate effects of. The same day I made an examination of the place and the neighbourhood of where the little cloud of dust was seen near the surface of the ground, and which was followed by the sharp, rattling sound that characterizes this variety of these mysterious sounds. I heard such a sound immediately preceding an earthquake shock on the 1st December at Cheviot, and considered that in that case the sound was produced in the air. Further description of both the incidents referred to will be found in the appendix to this report.

Conclusions.

These are simply the facts of the case, and may be briefly stated under different heads, as follows :—

1. That on the morning of the 16th November, 1901, a violent earthquake took place in the Cheviot and Amuri districts of Nelson, which had also great force in northern Canterbury, but rapidly lessened as it proceeded north through the Marlborough Provincial District.

2. That the origin of this disturbance was not, as at first supposed, a further displacement along the Kaikoura line of fault, or of the Great Clarence fault, as, had the disturbance proceeded from the Great Clarence fault south-west of the Waiau-ua Gorge, it must have reached Cheviot from the west, and the Hurunui–Waiau Plain must have suffered from its effects to a degree greater than was experienced over the Cheviot Estate. Neither did it proceed from an extension to the east-north-east of the western part of the Kaikoura line of fault, since all attempts to trace such an extension of the Kaikoura fault have failed.

3. That the greater violence of the earthquake was confined to the valley-depression between the coast ranges and the extension of the Lowry Peaks, Parnassus, and Mount Stuart Ranges from the Hurunui River to the Conway, the mountain-ranges in question being formed of old Secondary or Palæozoic rocks, while the valley between is filled by Cretaceous, Tertiary, and modern deposits.

4. That, though not referable as regards the cause to any of the ascertained lines of fault that have been explored in the district to the west and north-west, the greater force of the earthquake was manifested along a line nearly parallel to the Great Clarence fault, and displayed a more than ordinary violence at different points along this line, as at Mendip Hills Station, in the lower valley of the Leader, and along the eastern part of the Cheviot Estate, between the Jed and Waiau-ua Rivers.

5. That the rapid lessening of the violence of the great shock north of the Conway shows that the earthquakes were not due to fresh rupture along the northern part of the Kaikoura line of fault.

6. That, while the earthquake as a whole progressed in a nearly north to south direction, the resulting earth-rents had no corresponding regularity, but ran east and west or north and south, sometimes evidently controlled by the configuration of the surface, sometimes by deeper-seated causes.

7. That the rents formed at or reaching the surface of the ground were never continuous for more than 5 or 6 chains, more especially when they occurred in the low and alluvial grounds of the district. The statement that earth-rents ran from Mendip Hills Station to the banks of the Conway, opposite Ferniehurst, does not mean that any one rent was continuous along the line or for greater distance than has been stated.

8. That the violence of the great shock south of the Conway gradually lessened as it proceeded in that direction, and was less at Cheviot than at Mendip Hills Station, and that Cheviot suffered more than the district north of the Waiau-ua River simply because of closer settlement and a denser population.

9. That the great falls of rock from the cliffs between the mouth of the Jed and Port Robinson are not a proof of the extreme violence of the earthquake in that part of the Cheviot district—rather the rock-falls are a proof of the unstable character of the cliffs themselves. The comparative lightness of the great shock as experienced at the accommodation-house, not more than a quarter of a mile distant, may be cited in proof of this.

10. That the transmission of the shock was at a very slow rate, as described at several places in the above report.

11. That movable objects were as a rule shifted to the north-west in the Cheviot district, and to the south at Mendip Hills Station, in the Leader Valley. In the Cheviot district in one case the walls of a house fell to the east, but this was exceptional.

12. That, in comparison with the earthquakes of 1888 in the Waiau-ua and Hope Valleys, the earthquakes of 1901 in the Cheviot

and Amuri districts were not of equal violence, if rents and slips on or at the surface of the ground are to be regarded as proof.

13. That, as in 1888, the earthquakes of 1901 were accompanied by sounds proceeding from near the surface, or from considerable depth in the earth; and that, though these sounds are more frequent during times of earthquake disturbance, they also are common at times long preceding and succeeding the occurrence of earthquakes, and seem in some way to be connected with a peculiar condition of the atmosphere.

14. That on the assumption that the earthquakes of the district in the past have had some relation to the denudation of the mountain region, and the existence of the great lines of fault that have been or may yet be traced, and these being at least four or five in number, there are no means of safeguarding against the effects of earthquakes that may occur in the future, as it is totally uncertain what line of fault is next to be affected, and whether or not, as during the recent disturbances, a new line of fracture and upheaval is being formed.

15. That, owing to the increased quantity of *débris* carried by the rivers from the mountains of the main range to the eastern seaboard, there is a probability of the more frequent recurrence or greater violence of earthquake shocks in time to come than has distinguished past time, since these disturbances began.

16. That it is probable the scene of the next earthquake disturbance will be elsewhere than in the Cheviot district, and that, as there has been no serious disturbance of this part of the country for fifty years prior to November last, it is reasonable to conclude that a like period will pass before the district is again violently disturbed by earthquake action.

17. That, though on this occasion something further has been added to our information as to the behaviour of earthquakes, and although they may be classified and some of their more proximal causes indicated, the earthquake as a whole still remains a visitation and a mystery.

I have, &c.,

ALEX. McKAY.

The Under-Secretary for Mines, Wellington.

APPENDIX.

THE following interim reports to the Under-Secretary for Mines are the result of observations made at the time they were written. The opinions expressed may not conform to the conclusions finally arrived at, but they show the process by which the conclusions stated in the report have been arrived at :—

SIR,—

I left Wellington for Cheviot on the 20th November, and the following day arrived at Christchurch. The same day I went by the afternoon train to Amberley, and on the 22nd took coach from the Waipara Railway-station, arriving at Cheviot about 4 o'clock p.m., in time to have experienced a smart shock of earthquake which took place about that hour. This, however, was not felt nor noted by me at the time of the occurrence.

Of what happened at Christchurch I have made but little note. Naturally I had a look at the spire of the Cathedral, and, although a slight shift of the upper part is to be detected, this is not obtrusive, and requires to be looked for to be seen. Some repairs have been effected since the shock of the morning of the 16th by which it was damaged. Although the principal shock of the 16th instant was violent in Christchurch and the neighbourhood, but little damage to buildings took place, and any excitement that at the time existed might ere this have been allayed were it not that daily reports are coming from Cheviot which show that the disturbances there have not yet ended. There is some alarm at this continuance of earthquake shock at Cheviot, and a good deal of sympathy with the settlers who have suffered by the partial or complete destruction of their homes. Nor is this lessened by the eagerness of the Press after the smallest item that deals with what is called "stricken Cheviot."

In Christchurch the principal shock of the 16th instant was described to me as commencing with a long swinging motion, the direction being north and south or north-west and south-east. When this had passed, a general shaking from no particular direction—or, rather, from all directions—took place; and to the narrator it seemed as though the house by the four corners had been seized in the grip of a giant and shaken till all movables and loose articles rocked to and fro. Yet very little breakage took place. When the account as above given was finished I came to the conclusion that an earthquake of more than ordinary severity had taken place; but in

Christchurch and its neighbourhood it did not have a destructive force equal to that of the 1st September, 1888, nor was it greater in violence than numbers that have taken place since 1869.

On leaving Christchurch for Amberley we passed through Kaiapoi and Rangiora without noting any effects of the recent earthquakes. It was reported in the Press of Christchurch that at Kaiapoi the earthquakes of the 16th instant were felt with great violence; that at some places the earth opened and water and sand were emitted from rents in the ground, and that at one time an inundation by water from this source was apprehended. I have just learned that like emissions of water took place on some parts of the Cheviot Estate, and that creeks that before the 16th instant were without water in their beds are now streams of considerable volume, although in the meantime no rain has fallen. Some increase of the water in such cases may reasonably be allowed probable, but that in some instances the creeks immediately after the earthquake were "bank and bank" is hardly credible. Neither at Rangiora, Sefton, nor Balcairn was anything seen that in any way indicated violent earthquake action. At Amberley the parts of the chimneys above the roof of the Railway Hotel had fallen; but, excepting the reports, which every one was willing to give, that the earthquake had been unusually severe, there was really no evidence of its having taken place other than what has been stated.

At Leithfield, east and abreast of Balcairn Railway-station, the earthquake was felt perhaps with as much violence as at Amberley. There I was informed by Mr. William McAdam that at the time of the shock on the morning of the 16th instant he was in his sitting-room, and observed the undulations of the ground affecting even the floor of the room in which he sat. Mr. McAdam was facing the south at the moment, and he informed me that there was a strong tendency to be precipitated on to the floor and in that direction. This would imply that the shock came from the south, yet there cannot be a doubt that the first great impulse came from the north-west.

Between Waipara Railway-station and Cabbage-tree Flat, along the valley of the Omihi Stream for a distance of fifteen miles, not the least signs of recent earthquake action could be detected, and I looked carefully for all the minor evidences of such an occurrence. This absence of evidence of the kind expected was to me surprising, the more so as within a comparatively few miles the earthquake was said to have been very severe—as, for instance, at Stonyhurst, on the coast, a few miles north of Cabbage-tree Flat. At Cabbage-tree Flat two chimneys of the accommodation-house had the parts above the roof thrown down, but no damage had been done to the building nor to the contents.

I made some inquiries as to the nature and severity of the earthquake shocks lately experienced, but could get no very intelligent account, nor more than that they had had enough of the earthquake, and would be well satisfied with the assurance that they were things of the past.

Leaving Cabbage-tree Flat, the broad flat saddle intervening between there and the deep valley of the Gretta showed no sign of earth-rendings, or of the downthrowing of the edges of the shingle and clay cliffs bordering the road to the Hurunui Bridge and Cheviot.

At the southern end of Pendle Hill, where the road to Stonyhurst leaves the main road, signs of earth-shaking began to appear. The Greta Valley towards its upper end is filled with Saurian beds belonging to the Waipara series of Cretaceous age, and on these rest thick gravel and silt deposits of a lacustrine character and probable Pleistocene age. Lower down the valley the beds are soft Tertiary clays and clay marls, which yield readily to atmospheric agencies, but are yet by the action of the Greta cut into high cliffs, from which waste, whether after a spell of dry or wet weather, is abundantly thrown into the creek or on to the road. A number of small slips had taken place, due to the earthquake, but these were in no way remarkable, nor more than might be expected from the weather under the conditions alluded to.

Crossing the Hurunui River by the bridge at the lower end of the gorge, between Ben More Range and the hills on the south side, we entered on the river-flats within the Cheviot Estate. At first, and for some distance along the road, there was not the least signs of recent earthquake action, neither on the low grounds nor on the slopes of the Ben More Range to the west. After rising on to the second terrace, and approaching the somewhat scattered Township of Domett, houses near the road-line and within the township were found to be usually without chimneys, or at least chimney-tops; otherwise, with one exception, the houses themselves appeared to have sustained no damage. The exception referred to was a wooden cottage which stood on the flat close to where it terminates against the lower slope of the range to the west. The cottage seemed to be leaning towards the west, but I had no opportunity of making a closer examination as to the amount of damage it had sustained.

Only one brick or cement chimney in the Township of Domett seems to have withstood the shock. This was an interior two-flue chimney, the longer side of which was in a north-west and south-east direction, a circumstance which in all probability tended to its better resistance of the earth-vibrations, and left it as an almost solitary memento of what had been in the way of chimneys. Another

chimney formed of cob or sods had resisted the force of the earthquake. The house to which this chimney is attached seemed in nowise injured, and in this respect is singular among all the cob and sod houses on the Cheviot Estate, which, from what I have seen and heard, are all, with this exception, levelled to the ground.

So far, apart from tumbled chimney-tops, there were no evidences of a violent earthquake having taken place. There were no slips on the hillsides, no breaking-down of the overhanging parts of creek-banks and road-cuttings, up till within less than three miles of "stricken Cheviot." I had expected things to be different, and felt disappointed that they were not as reported. Nor was this feeling lessened when, on passing the saddle leading into the upper part of the watershed of the Jed, the Township of Mackenzie came into view, its buildings still erect and brightly reflecting the afternoon sun. Surrounded by dark plantations to the north-east and south-east, the township, situated where the broad flat narrows into the vale of the Jed River, looked beautiful, and gave not the slightest evidence that it had suffered from the violence of a destructive earthquake, and from what could be seen (from less than a mile distant) there was here no "stricken Cheviot." The township looked the very ideal of a country town, in nothing peculiar save that it was smokeless because there were no chimneys.

Driving through the township as far as the post-office, it was noticeable that a great number of window-panes were broken, the glass from which littered the pavements. There were also an undue number of tents pitched on vacant sections and sections on which buildings stood, a remarkable fact, seeing that when last visited the Township of Mackenzie was extra well provided with boardinghouses and pseudo-hotels. There was a considerable crowd of people, mostly of the hardier sex, congregated about the post-office and the central part of the township, and a great number of buggies and other means of sudden and rapid exit from the place. Most of the people were evidently somewhat excited (they had within the last quarter of an hour had their last shake, and this was evidently still under discussion). My immediate business was none of theirs, and I had some difficulty in finding storage and lodging for the night. Finally the difficulty was overcome, and in the evening I arrived at this place, about two miles to the east of the township.

On careful inspection it could not be denied that the township in many of its buildings had sustained damage. I saw the wreck of the butcher's shop, a brick building, which had been thrown down by the earthquake. I entered one or two stores in which, though partly rearranged, the contents still gave evidence of considerable disorderment. Some of the houses had shifted somewhat consider-

ably on their foundations, and I saw piles of bricks that had once been chimneys or chimney-tops, but which had fallen and had yet cohered *en masse*.

We left the township by a road going towards the north-east, past the woolshed and dip of the one-time Cheviot Hills Station. The dip, constructed of brick as far as the building was concerned, was badly wrecked, and a cob building adjacent had the walls and the roof down. Neither within the township nor anywhere else up to the present had earth-rents been noticed, but immediately beyond the dip rents due to the earthquakes appeared on the road and along the banks of the creek (a branch of the Jed, which, rising on Mount Caverhill, flows west and south to join the main stream immediately south-east of the township). These rents were not of a serious nature, but being the first that have come under my notice in connection with my work here they deserve mention. They were not more than 2 in. to 3 in. wide, and traffic on or repairs to the road had filled them in again, so that they were traceable only by the fresh break in the road-metal. Nor were the rents which appeared along the banks of the creek of a serious kind; though numerous, they were not wide, and seldom ran for any considerable distance, nor in straight lines. In most instances they appeared to be nothing more than the yielding of the bank or face of the creek-terrace, where, under violent shaking of the ground, the soft valley-bottom had been unable to support the edge of the adjacent terrace. Many rents of this kind appeared on both sides of the creek for the next third of a mile, beyond which the road, turning more to the east, crosses the creek. Here a cutting leads into the creek-bed, and by a like cutting the opposite terrace-bank is gained, the creek-bed and low ground between the two high banks being not more than 40 ft. in width. Under the high bank on each side of the creek ran an earthquake rent 6 in. to 8 in. in width. In both cases there was a downthrow of about 1 ft. on the creek side of the rent, from which it would appear that the whole of the space between had sunk by that amount. This is a very curious fact, and if an explanation at the present stage of my investigations is to be attempted I can only account for it by supposing that the shaking-together of the soft floor of the valley consolidated the earth material and expelled the water, and the whole in this way sank after the manner of a drained swamp. A number of settlers' homes stand on the banks of this creek between the township and the crossing referred to, which in all cases had suffered severely, and were, when the walls were of cob, completely thrown down. Weatherboarded houses were still standing, though chimneys in every case had, in the parts above the roof, been thrown down, and in some cases the walls of the houses

were disturbed and in winding. In most instances they were considered unsafe to live in, and tents were pitched within the grounds, in which the settlers passed the nights, even though they occupied the houses during the day.

Beyond the creek-crossing the road runs along a terrace-flat to the low hills forming the lower western slopes of the Cheviot Hills or coast range. For some distance farther the road has the hills to the south, and a swampy flat on the northern side of it. The road is 10 ft. to 14 ft. above the level of the swamp, and at one place particularly there has been a considerable amount of damage done to the road, the lower side towards the swamp having sunk down, and earth-rents, in some cases fully 18 in. wide, have been formed. These, though imposing, were still of the nature of those farther down the valley, and were slips rather than true rendings of the solid earth. Yet farther on were some less prominent rents of the same kind, but shortly after passing these no further evidence of disturbance by earthquakes was met with till arriving at the farm of Glenkens, where I lodged for the night.

Glenkens, 23rd November.

During the day a strong nor'-wester continued to blow, which made it impossible to do any photography, and rendered work of any kind very unpleasant. I, however, went to Mackenzie and made a cursory examination of many of the buildings affected by the earthquake, and a more particular examination of some. On closer examination it is seen that a greater number of buildings have sustained more damage than at first sight was apparent.

Something has been said in the newspapers as to the condition of Penberthy's Hotel, one of the largest buildings in the township; and photographs have been published showing the appearance of the place subsequent to the great shock of the morning of the 16th instant. These, however, do not impress one that the condition of the building is as has been reported. The house was a two-storied building, containing six rooms, pantry, and scullery below stairs, and above two large rooms towards the west, with bedrooms and bathroom towards the east. The whole building was shifted to the west about 1¼ in. At the western end there was an apparent shift both to the north and to the south, but this was due to the side walls moving forward to the westward while the middle part of the house remained stationary. The result is that the front is concave, and the sides are thus drawn inwards both from the north and the south. The upper story yet stands vertical, but from the ceiling to the floor the lower story leans forward to the west and overhangs the end wall-plate 7 in. to 9 in., and the verandah is pushed forward in the same manner. The windows do not now fit in the

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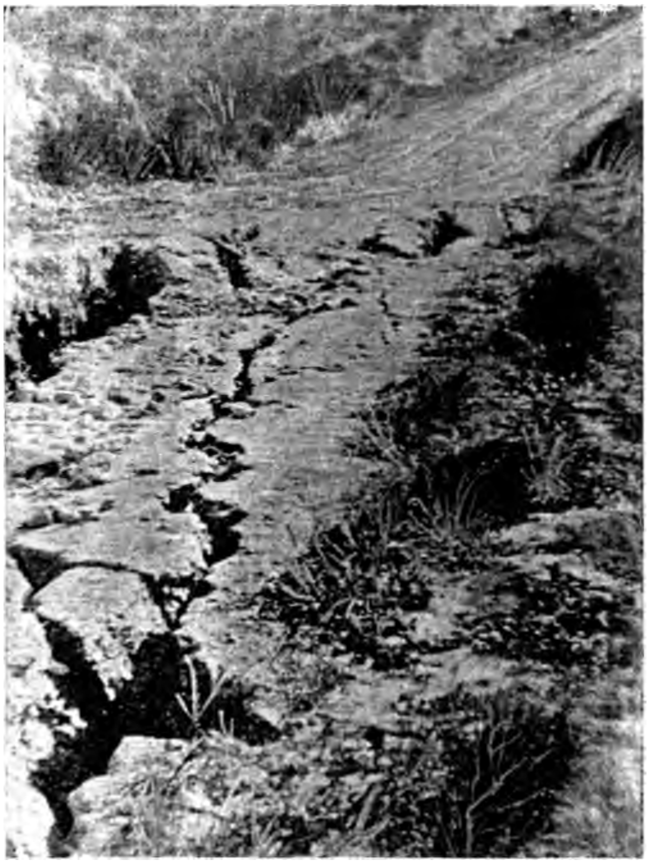

Earthquake Rents on Road, Mackenzie to Glenkens Cheviot Estate.

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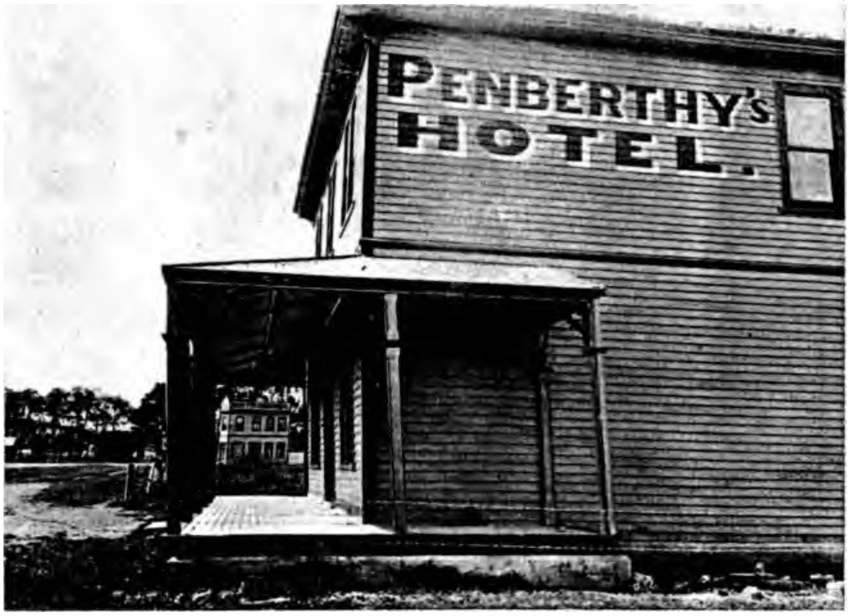
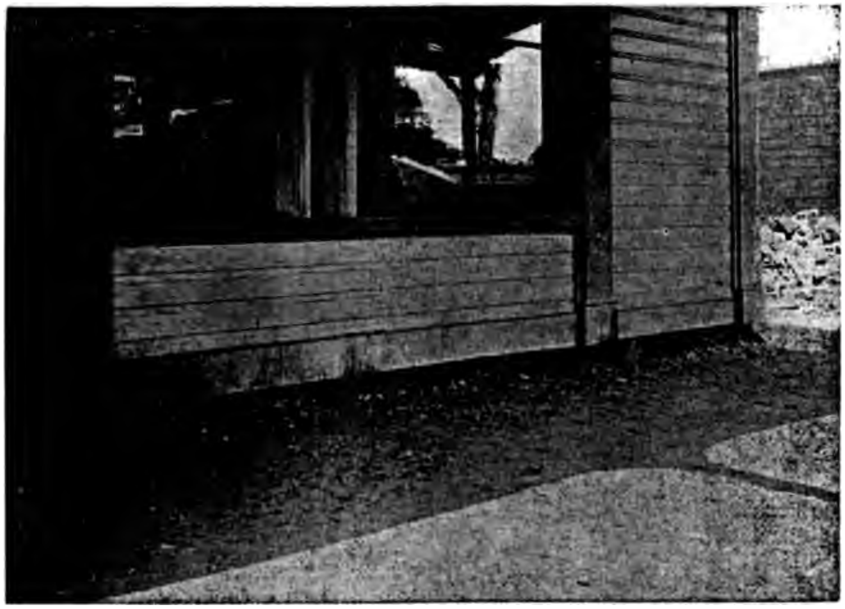


After the Earthquake: View in the Township of Mackenzie, Cheviot. [To face p. 46.



Store in Rolleston Street, Mackenzie, showing Shift to N.W., with Piles of the House leaning in that Direction.

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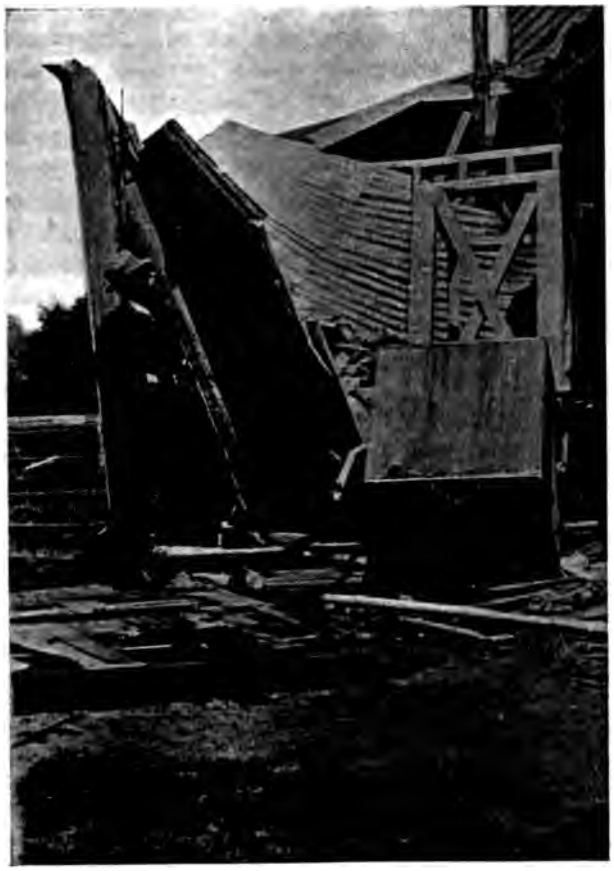

Back Part of Penberthy's Hotel, Cheviot, after the Earthquake of 16th November, 1901.

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casements from the same cause, but it is internally that the more remarkable effects of this movement of the lower floor are to be observed. The house was plastered throughout, and everywhere—in the hall, in the two front rooms, in the dining-room, in the kitchen and pantry alike—the plaster is cracked, or patches of it have fallen, and the walls present the appearance of a polished slab of light-grey much-veined marble. Between the front rooms and those in the middle part of the house chimneys ran through the upper floor and roof, and in all cases the registered grates and mantlepieces have been thrown out on to the floor, carrying with them a portion of the brickwork. In the southern front room the binding-bricks overlapping the joints of the bricks above and below were broken clean through, and the part of the wall left standing presented an even face, as though it had been cut down with a saw. The kitchen-chimney, the water-tanks, and hot-water apparatus for supply of the bathroom were completely wrecked. The chimney above, 5 ft. from the floor, was thrown into the kitchen, and formed a heap which extended to the middle of the floor and completely buried out of sight the cooking-range. Outside, the fall of the water-tanks carried with them a wooden lean-to structure, making a total wreck of this part of the building.

Scott's Commercial Hotel, of wood, was not shifted from its foundations. There was a good deal of breakage inside. The chimneys were formed of cement concrete, and, like all other chimneys in the township, the tops above the roof were thrown down. The basement parts were also rent, but not seriously. The rough concrete had been plastered with fine-sand cement, and to ascertain the state of the concrete this finer layer was broken through. It was then discovered that from the very foundation to the height of the jambs of the fireplace (in the case of the kitchen-chimney) the concrete was completely crushed, scarcely two pebbles cohering. The whole of the chimneys had therefore to be pulled down; and when doing so it was found that the concrete above the height mentioned was in good condition and strong, as well-made concrete should be. A brick chimney in the billiard-room was in part thrown down and wrecked to the very base. A small detached cottage was thrown bodily off the piles and shifted towards the west a distance of 2 ft., and minor damage was done to the outbuildings.

At the post-office all the chimney-tops were thrown down, the coping parts remaining solid after the fall.

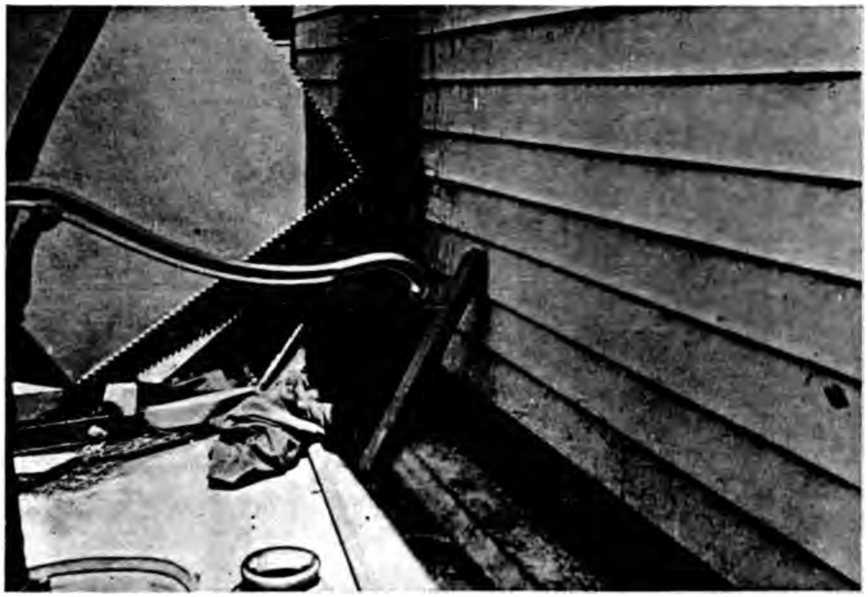
In Rolleston Street all the houses were more or less shifted to the north-west. Huddard and Hull's store shifted 7 in. in that direction, and in doing so dragged the piles the distance named, so that

they lean in a north-westerly direction. This building in its western part shifted from the piles, and the floor is in places broken and generally very uneven. Next to this, and to the north-west, is a brick building, which at the time when the earthquakes began was a butcher's shop. The north-western wall of this building fell and damaged the building adjacent on that side; the roof was displaced, and the other walls rendered so ruinous that for the safety of passers-by they had to be pulled down. The next house to the north-west—Jenkins's drapery and fancy-goods store—was also damaged, but not so seriously. Inside the stores mentioned, where goods were liable to breakage, there was very considerable loss sustained; but the *débris* was cleared away, and things are again somewhat in order, and the loss is not fully apparent to the stranger unacquainted with what the contents of the stores were. In one case I expressed the opinion that, so far as could be seen, the loss had not been great, but after I had been taken through the premises I left satisfied that there had been a considerable amount of destruction—more than at first sight appeared. In another case the living part of the house was much as it was on the day of the heavy shock of earthquake. The furniture in all the rooms had a tendency to be piled in a heap in the middle of the floor, and the piano alone had escaped a capsize. In the same room the bulk of the chimney, in the form of loose bricks, was in the middle of the floor.

I visited the newspaper office, and had shown to me the heavy printing-presses, &c., that had been shifted out of place; also Mrs. Moffat's boardinghouse, which at the south end had been shifted west 11½ in. and to the north 5½ in. This house stood on cement walls and piles, which on the west side were carried over by the movement of the house. A chimney at the south end of the house had been built of brick on a cement-concrete foundation. Between the first and second layers of brick the chimney had parted, and with the house was moved 11½ in. to the west. The chimney, though thus shifted, still cohered, though the upper part projected over the basement part by the amount specified.

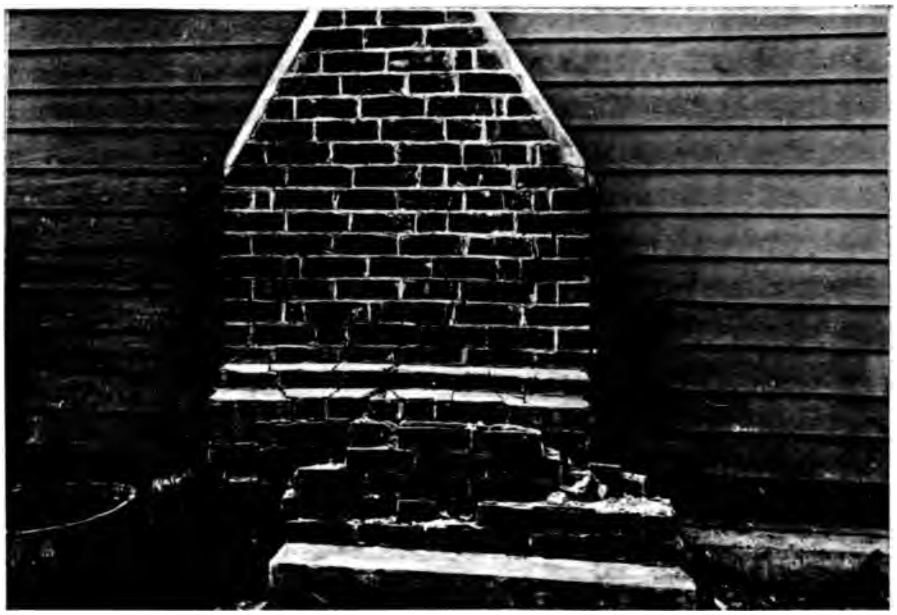
Glenkens, 26th November.

From the township I followed the Sinclair Road north-west to the butter-factory, said to have been damaged by the recent earthquakes. The damage does not seem to have been so great—at least, to the building—as was reported. It is true that the engine-boiler was torn from its setting over the furnace, and projected to the north-west a distance of 5 ft. 6 in. from its original position. The building was not displaced from its foundation, but leans to the westward some 3 in. As everywhere else on Cheviot, loose and movable articles were thrown about, and in this way some considerable damage



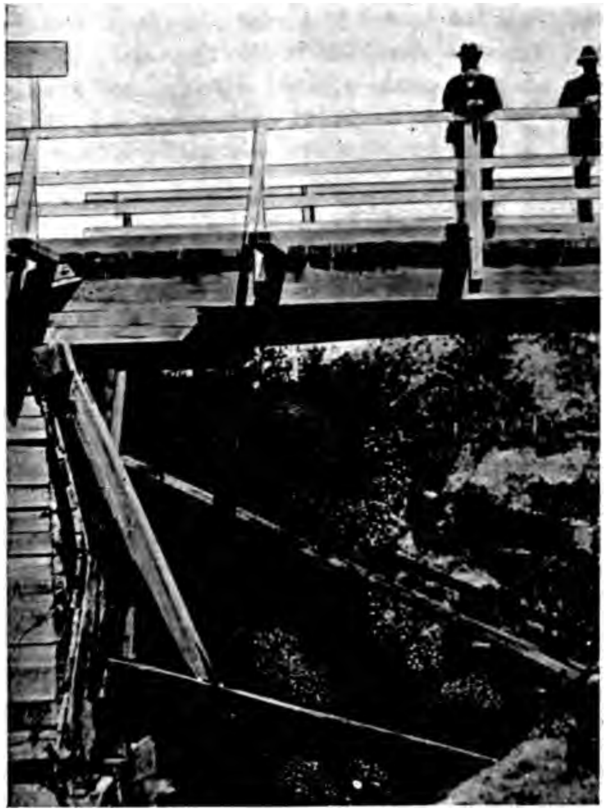
Effects of the Earthquake in Mackenzie Township, Cheviot: House shifted from its Foundations.

[To face p. 48.



Chimney displaced from its Foundation, and, with House, carried West, Mackenzie Township, Cheviot.

[To face p. 48.



cts of Earthquake: Damage to Bridge over Swamp Creek, Sinclair Road, Cheviot.

[To face p. 49.

was done. At the date under which I write a portable engine has been installed, and everything is going on as usual.

Further to the north-west the road crosses Swamp Creek by a bridge. The bridge, though not actually down, was wrecked and rendered unsafe. On the south-east side of the creek the piles are broken in the middle or split from the cap-piece for some distance downwards, and the strong beams supporting the earthwork outside the bridge on the south-west side are also broken. The embankment to the south-east has moved to the north-west. The beams and planking of the bridge and the piles in solid ground on the north-west end of the bridge have resisted the movement, and as a result the pressure on the southern side bellied and broke the piles.

On the north-west side of the creek an earth-rent some 6 in. in width runs for a short distance along a gully and small creek parallel to the road-cutting by which the higher land to the north-west is reached. On the southern bank of the creek, and down-stream from the bridge, the high bank of the creek is much torn, and for a distance of about 3 chains a great deal of wreckage has been thrown into the creek-bed. Eight or ten chains nearer to Mackenzie the road-cutting descending from the higher terrace into the creek-flat is partly obstructed by material which has fallen from the high bank on the west side of the road, and along the face of this upper terrace earth-rents are to be seen, some of which appear to be horizontal partings of the strata, which here consists of gravel, silt, clays, and loam.

Beyond the crossing of Swamp Creek till reaching, farther north-west, to the Leamington Stream (on the maps called the Gower River) no signs of earthquake action were detected, and following up the Leamington for some distance nothing of the kind was to be seen.

Below Mr. Gardner's homestead the road by a deep cutting passes through a spur of Tertiary clay, and from the north-west side of this a considerable fall of rock has taken place, and the road is obstructed. Higher up the valley earth-rents begin to appear, running irregularly, but generally conforming to the direction of the adjacent higher ground, and along or sub-parallel to the foot of the terraces. Passing on to the high terrace-flat above Mr. Gardner's homestead there were no evidences of a serious earthquake having recently occurred, except in fallen chimneys. Without exception the chimneys seem to have fallen throughout the whole of the northern part of Cheviot. On this upper flat I called at Mr. Sloss's farm to make inquiries, and learned that considerable falls of rock had taken place higher up the valley, but that in the immediate vicinity the chief or only displacements had taken place on the old slips on the

opposite or west side of the Leamington, and along the road to Mackenzie by way of the upper part of Swamp Creek–Frog Hall Road.

The road from the saddle between the Leamington and the upper part of Swamp Creek descends the range along and under a series of high clay cliffs capped with gravel-beds. Great quantities of *débris* have fallen from these cliffs, and at many places had obstructed the road, but for days a party of men have been engaged on the work of clearing the fallen material away, and the road is now passable.

Elsewhere along the road to Mackenzie there was little or no evidence of an earthquake having taken place.

Glenkens, 28th November.

Went by way of the Jed Valley to Gore Bay and Port Robinson, and noted the effects of the recent earthquakes along the Jed Valley and on the coast-line between the mouth of the river and the landing-place. Below the Mansion House and manager's residence the valley of the Jed has not been greatly disturbed. On the flat, above the lower and more gorgy part of the Jed Valley, there are a few rents that are of the usual description—namely, rents of a superficial character between the soft ground and terraces at a higher level. One such rent crosses the road about two miles from the beach, where the road alters its direction from a westerly to a more northerly direction.

In the lower part of the valley the road, as a side cutting, runs along the face of the high cliffs on the south side of the valley. Along this part a good deal of talus-slope material has been set in motion by the earthquakes of the 16th instant and the more violent earthquakes that have since taken place, but in no instance have the rocks *in situ* been dislodged or thrown down. This is somewhat remarkable, seeing that not more than a mile distant the cliffs of the sea-face overlooking the Bluff Road to Port Robinson were much shaken, and from rocks *in situ* there was thrown down such enormous quantities of material that the road for over a quarter of a mile has practically disappeared, being buried under the talus-heaps thus formed. The reason why the cliffs along the lower Jed suffered so little in comparison with the cliffs on the sea-face seems to be that they run in nearly the line followed by the earthquake in its progress from north-west to south-east, and why the bluff on the sea-face suffered so much seems to be that the line of the cliffs was nearly at right angles to the propagation of the waves of earthquake disturbance.

The great slips on the Bluff Road are very imposing, perhaps more than anything of the kind to be met with over the whole of Cheviot, but they do not manifest the greatest intensity of earthquake action.

The unstable character of the cliffs and the danger of such slides as have taken place were matters of remark prior to the occurrences of the 16th November last. The largest slip of all is a slide from a rock-joint, or "dry back," that, though precipitated by the earthquake, must have come down at no distant date through atmospheric agencies alone; and the same may be said of the lesser northern fall of rock. The slip between the point (Cape Horn), where the cutting is two-sided, and the southern end of the bluff is mainly composed of matter from the higher part of the cliff, no serious disturbance of the lower part having taken place. The central slip, immediately north of Cape Horn, contains the greatest bulk of rock-matter, and will require the greatest amount of labour to clear away, as a large part of it, consisting of comminuted rock, is lodged above the level of the road. The northern slip is not so large, but there are many fissures in the face of the cliff above this, and the loosened rock should be thrown down before commencing to clear away what lies on the road-line. The southern slips in bulk are little more than lies within the angle of rest from the outside of the road-line and the cliff on the opposite side of the road. In the case of the middle slip the excess of material has overrun the outer side of the road and built up the angle of rest from the sea-beach. A much greater depth of material, therefore, lies on the roadway, and stretches up the steep slope on the landward side of the road. Rents were formed some distance back from the face of the cliffs, which, running across the Cathedral Road, may some of them reach as far as the cliffs overlooking the Jed River in its lower part. Most of them must stop short of reaching thus far, as I saw but one rent, and that only a narrow one, crossing the road and striking across the Jed cliffs in the direction of the bluff.

In the near vicinity of the Bluff Road and the cliffs the great shock of the 16th November was moderate compared with its force toward the township and along the western slopes of the coast range between the Jed and the lower gorge of the Waiau-ua. As usual, chimneys were thrown down, but in the accommodation-house, not more than 250 yards from the north end of the cliffs on the Bluff Road, loose or light articles, whether facing the west or the east, were not thrown down. The chimney fell through the roof of the kitchen, and in the fall there was a general smash of the contents of the breakfast-table, and a narrow escape of some of the inmates being killed.

Glenkens, 29th November.

From the township I followed the Parnassus Road as far as Mr. James Butt's farm. On the way I examined the bridge crossing Swamp Creek, a little to the north of the butter-factory. This was

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not seriously damaged, and repairs were being made at the time I passed. The workmen told me that there was indication of the coming-together of the two banks of the creek, and this may be regarded as reasonable, seeing that there are earth-rents on both sides of the creek-channel, and the opening must be in the direction of the least resistance or less-supported side of the fissure. Several rents, 5 in. wide, were on the road on the northern bank of the creek, and some of these ran into and showed in a low spur adjacent to the bridge.

About a quarter of a mile further along the road we passed a house the walls of which were of cob or sun-dried brick. The walls were thrown down, and the roof had been let down on top of the ruins.

A short distance further brought us to the residence of Mr. T. L. Macfarlane. Mr. Macfarlane occupies a small section of land, some 12 acres in extent, upon which he had made his home, and had done much to make himself and family comfortable. The situation of the house was on the point of a low spur, closely overlooking Swamp Creek. The house was a square building, about 30 ft. in length and breadth. The walls were of sun-dried brick, as were also the inside partitions. A verandah had been recently added on the south-east side, and the south-west wall was protected by weatherboarding against the storm from that direction. The roof was of iron. Inside the house was neatly finished and well furnished, and, to the pride of the occupants, was thus reputed and spoken of throughout Cheviot. The first great shock of the earthquake threw down all the walls outside and inside, except that on the southern side, which was supported by the weatherboarding. Due to the support on this side the roof slipped off more to the north than to the west.

At the time of the first and great shock of earthquake only Mrs. Macfarlane and a young girl were in the house. Mrs. Macfarlane was in the kitchen, and, observing the southern wall in movement, she made her escape from the house to the south-east, but had not got beyond the verandah more than 2 ft. when she was thrown down on her hands and knees, and from this posture was unable to regain her feet or move farther towards safety till the first great shock had passed. The child also had a narrow escape, but succeeded in avoiding the falling walls and other *débris* thrown in different directions. By the time I had an opportunity of examining the place the interior of the house had been cleared of the walls that had fallen inside, but enough could be seen to convince any one of the force with which the walls had been thrown down, and the completeness of the disaster that had overtaken the place.

f Macfarlane's Cottage, Parnassus Road, Cheviot, after Earthquake of 16th November, 1901.

[To face p. 52.]

Absolutely nothing was saved whole and uninjured. The legs of the piano were driven through the floor, and was otherwise so injured as to render it useless. An American organ shared the same fate, and a sewing-machine became a mixture of broken wheels and fragments of iron castings. A specially strong table had its legs punched through the floor, and at the same time the top and rails of the frame were splintered and broken beyond repair. A large bedstead of iron had thrown upon it as much wall as it could contain, with the result that, where not broken in its stronger parts, it is bent and twisted in a most extraordinary manner, and constitutes a very curious study. Wardrobes and presses, when not smashed beyond recognition, were at least rendered useless; and of all the larger articles which the house contained the kitchen-range was the only one which escaped comparatively uninjured. The pantry and its contents were demolished, and the contents generally became such that, on excavation, they had to be removed and buried. Only a few bottles of home-made wine, which represented and were the survivors of a battalion six dozen strong, were dug out of the rubbish in an unbroken state. Ornaments, pictures, photographs, articles in china and glass, frames, brackets, &c., amounted to three barrow-loads of unrecognisables; and, saved from this heap of rubbish, the lady of the house had a melancholy pleasure in contemplating portions of a magnificent opal portrait of Mr. Macfarlane and herself, taken many years ago, the loss of which is beyond the power of man to replace. A photograph of the exterior of this house, as it was after the earthquake, appeared in the Christchurch papers, but this conveys not the faintest idea of the ruin and disorder of the interior.

A mile farther to the north-east, along the course of Swamp Creek, is the residence of Mr. James Butt, on which and in the vicinity of which the earthquake was perhaps exceptionally severe. Approaching the place by way of a bridge across Swamp Creek, signs of earth-rents that crossed the road, but had been filled in, were numerous, and many rendings showed on the banks of the creek. The stable and outbuildings of the farm-steading, though not thrown down, yet suffered severely, and a very pronounced earth-rent ran across the barn-yard. The dwellinghouse had all the chimneys thrown down, and was shifted on its foundations 16 in. to the westward and 10 in. to the north, and in the shift to the westward the interior chimneys, moving on their foundations, accompanied the woodwork. The walls, which were lath and plaster inside, sustained serious damage.

Of movable articles inside scarcely anything breakable was left unbroken, and, as usual, the contents of the pantry were

completely demolished and thoroughly mixed. This, however, happened everywhere. As the house had departed from the cement walls and piles on which at first it stood, the floors were very uneven, and at places broken. Necessarily great damage was done to the furniture, and the better rooms had been fully and luxuriously furnished. I will mention specially but one article, the hall-clock. The lens-shaped ball of the pendulum was of brass, and in some unaccountable way this got dented, not on the crown of the convex surface, but on the side thereof, which damage must have resulted by its being thrown against the glass of the case, and yet the glass was not broken.

Returning to Mackenzie by a different route, we passed the house in which the child was killed by the fall of a mud wall during the continuance of the first or big shake of the 16th November. The house, owned by Mr. Paterson, was at the time occupied by Mr. Johnson. It is situated about a mile north from the township, near the top of a saddle forming the water-divide between a south branch of Swamp Creek and the water flowing south into the Jed River. Externally the house shows that it suffered considerably, but it must be entered to see what the full force of the earthquake had been.

The walls of the building were of cob, and the roof was of iron. The interior area was divided into six rooms by rather heavy partitions of cob material. The external walls were especially strongly built, bands of hoop-iron being laid between the different courses of cob, which specially showed in the interior partitions. There were no earthquake rents in the ground in the vicinity of the place, and at first sight it might be thought that the earthquake was not more violent here than in the Township of Mackenzie. The house might be entered with equal ease by the door or either of the two front windows. The door was blocked with masses of cob, and the cob walls around the windows had been levelled to a convenient height. Inside all the partition-walls had fallen, and filled the place with fragments, generally about a foot in length and breadth. These fragments of the fallen walls were almost all of them resting on their diagonal angles, and covering the floors one or two pieces deep, and presented an extraordinary sight.

Indiscriminately mixed with the fragments of the walls were broken furniture, books, musical instruments, and a number of photographs which seemed to have been on the walls. In one small room was a basket of clothes that seemed to have been on the drying-ground the day before the earthquake took place. On the top of this several pieces of cob were lodged. A sofa, or the wreck of it, was overturned against and partly on to the kitchen-table. The top part of the chimney had fallen down the flue, and the cooking-

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range was buried under a pile of loose bricks. The front wall had fallen in, and the back wall had fallen out, or to the west. The interior walls had fallen, some of them to the west and some to the south. The end walls stood best, and, though rent, were not thrown down. I have mentioned that the cob of the walls had broken mostly into small pieces. In the room where the child was killed there was an exception to the rule. Looking into the room, what had been a wooden bedstead was seen to be broken and crushed to the ground, the mattress being still in place. To the west of the bedstead was a piece of the partition-wall between this room and the kitchen. This fragment was about 3 ft. 6 in. square, and had fallen into the bed, with the melancholy result already alluded to. An attempt to photograph the interior of this house was, I hope, partly successful, but the photograph must fall far short of the reality.

This afternoon I visited Donegal Street, on the western outskirts of Mackenzie. There I examined two ruined houses of cob that had fallen to the very basement tier of cob. The roofs fell, the one to the west, the other to the east, and in both cases a distance equal to the height of the walls from the vertical of the outer face of the walls. In the case of the house more to the south the last or basement tier of cob was turned upside down.

Glenkens, 30th November.

While at Macfarlane's I examined a ploughed field about 7 ft. above the level of Swamp Creek. At nearly a dozen places there had occurred at the time of the great shock an emission of water, carrying, also, quantities of fine sand to the surface. The spouting of water ceased immediately after the earthquake, and the sand now forms a deposit a few inches thick on the surface of the ploughed land. Carefully examining these patches of sand, it was noted that wherever they appeared there was a short rent in the ground, never more than 7 ft. or 8 ft. in length. The sand had partly obliterated these rents, but at two or more places along the line were funnel-holes, or minute craters, whence the escape of water had been more powerful or longer continued than along other parts of the line. I photographed two examples of this rather singular occurrence of the effects of escaping waters.

At another place higher up the valley of Swamp Creek I examined a gravel cliff forming the limit of the alluvial plain extending west and north-west of the Town of Mackenzie. As seen along the face of the cliff fronting the lower grounds along Swamp Creek, the material forming the terrace plain consists of moderately coarse and finer gravels, with beds of silt or loamy clay. Between two of these strata a parting had taken place, and gravel displaced had prevented the stratum above and below again coming close together.

The result is that along the face of the cliff a horizontal rent can be traced, and it seems likely that, as a result of such movements, escapes of water took place at several places on Cheviot Estate, and it may be from a like cause at Kaiapoi.

Glenkens, 2nd December.

In reference to conditions that may facilitate, even though they are not the real cause of, an earthquake such as has been experienced in this district during the past three weeks, I may mention that since the great shock of the 16th November no single shock, light or heavy, has occurred, except during a complete cessation of the wind and a more than ordinary stillness of the atmosphere. For months there has been, over the Amuri and North Canterbury districts, a prevalence of strong north-west winds, which blow hard during the day, but often, though not always, die away after sundown. On the 16th November it was calm at the time of the occurrence of the great shock, and all the succeeding shocks have happened during periods of calm, or a temporary lull of the nor'-wester, and it has come to be regarded as indicative of the probability of an earthquake to follow should the wind cease to blow.

Since my arrival at Cheviot all the shocks that have occurred up to the present have without exception taken place when the wind was lulled. During the early evening the wind blew hard, and gave every indication that it would continue through the night. At the present moment, and for the past quarter of an hour, there has been an excessive and suspicious stillness of the atmosphere. As I penned the last sentence, at 9.56. p.m., the expected earthquake came from a northerly direction, and passed away to the south. The stillness continues, and there is with me the premonition of another shock yet to come. The shock just experienced was of long continuance, but not of a very violent character; it could not, however, be regarded as a light shock. It shook the house considerably, and made the iron on the roof rattle.

Booming sounds preceding and following earthquake shocks, as mentioned in a previous letter, were heard at Cheviot before my arrival, but no particular importance seems to have been attached to them by the residents in the district. As a matter of fact, these sounds are often heard in all parts of the Amuri district, and at times when no earthquakes are being experienced. They have, however, been comparatively rare on Cheviot, and affect more the neighbourhood of the higher mountains. On Friday last such sounds began to be more particularly noted as preceding or following earthquake shocks, or occurring without being accompanied by an earthquake.

I believe I heard such sounds earlier in the week, but did not connect them with the occurrence of an earthquake. However, last

night there could be no mistaking the fact that they are in some way connected with the earthquake shocks that at the present time are so common. Last night I wrote, and continued writing till about 1 a.m., and retired to bed at that time. I did not go to sleep for an hour, and during that time became conscious of a strange creaking of the timbers of the house. I am aware that the cooler night succeeding a hot day causes the shrinking of the parts of a house, during which are produced sounds that might be mistaken for what I heard; but, knowing the nature of the noise due to shrinkage, I believe the sounds I now refer to were not of that kind, but gave the impression that the house bodily moved, although no movement of the ground could be determined.

Shortly before 2 a.m. a sharp report was heard. This was much louder than the crack of a rifle and less than that of a cannon. It was of the nature of a double sound, and is best rendered in writing by the word "*rat-tat.*" I was convinced that the report originated in the atmosphere not greatly but at some distance from the ground, and north of where I heard it, perhaps a quarter of a mile. A few minutes after hearing the report a series of gentle undulations of the ground began. The motion was a long swing, and if an earthquake can at all be a pleasing thing this was not unpleasant; and to tell the truth I enjoyed the rocking motion. There were three distinct movements in this the first shock. After a pause of a few seconds a second shock exactly like the first was experienced, and after a like interval a third that in no way differed from the other two. After this all seemed to be quiet, and I composed myself for some needed rest. Shortly before 4 a.m. I awoke, and though the wind had risen before I went to sleep it was now calm. I noticed the calm, but did not anticipate what was about to follow. At 3.59 a.m. there occurred what by many is considered the heaviest shock of earthquake that has been experienced since the 16th November. This was the shock of Monday, the 2nd December. I rose to note the time, and had just done so when a dull thud and a booming sound proceeded from the earth, as I judged, at some distance to the north of where I was. This sound was quite different from that which preceded the earlier gentle shocks that occurred at 2 a.m., and which seemed to be in the atmosphere. Both, however, seemed to come from the same direction, and to have originated at about the same distance from the house where I lodged.

Glenkens, 3rd December.

In a previous letter I described what was to be seen on the road from Mackenzie north-east to the western base of Mount Caverhill, the highest point of the coast range between the Jed River and the

lower gorge of the Waiau-ua. Abreast of the lower slopes of Mount Caverhill the valley turns to the south, and gradually the more swampy ground is left behind, and the last of the flat lands forms a stretch of good soil which is not marshy. This may be 10 or 12 chains in length by from 5 to 6 chains in width. Above this there are no flat lands of any extent in the valley of the main creek or those of its tributaries.

The upper or dry flat forming part of the small grazing-run occupied by Mr. Dougal Maclaren shows earth-rents at some distance from the creek or the foot of the hill-slopes on each side of the low ground. These may be regarded as true earthquake rents, differing in character from most of those in the lower part of the valley and near Mackenzie, or on the north bank of the Jed near the Mansion House. Above Glenkens homestead there are a number of small alluvial flats on each side, but mostly on the east bank of the creek. These show numerous rents, 2 in. to 5 in. wide, which cross the valley or follow the direction of low terraces formed by the creek when at higher levels.

The main stream comes from the south—a north-eastern tributary from Mount Caverhill—and immediately below the junction Glenkens house stands on a low spur on the east side of the creek. In the valley of the branch creek coming from Mount Caverhill there are a number of earth-rents, some of which are 4 in. or 5 in. in width; but it is on the steep spur east of the house that rents are most numerous, and these also are traceable for a greater distance than in the low grounds of the branch creek.

I followed some of these a distance of 4 or 5 chains, and found them to be open for a considerable depth, and most of them admitted of a walking-stick being thrust in to its full length without meeting any obstruction. The rocks here are old Secondary or Palæozoic sandstones and shales, and the rents run in a north-west and south-east direction, and would, if continued, pass directly under Glenkens house. But the low point of the spur on which the house is built is formed of young Secondary chalky limestone, and all the rents seem to have stopped short at the junction of this with the older rock to the eastward. The limestone here is soft as an ordinary chalk-marl, and its more plastic character may account for the non-continuance of the rents across it. This limestone runs south, and forms the higher and west slopes of a range of hills on the west side of the upper part of Glenkens Creek. The limestone for some distance forms crags on the top of the range.

The earthquake of the 16th November dislodged several large masses of limestone rock, which were precipitated by sliding or bounding down the steep slope to the low grounds. One specially large

mass was examined by me. This was 10 ft. by 7 ft. by 7 ft., and its course from the parent rock to where it now lies could readily be traced. At first it slid for some distance, but gaining speed it then for the rest of the distance bounded in leaps of 1 to 2 chains, and every time it came to the ground it made a depression about 2 ft. below the general surface. Finally it fell on its flatter surface and came to rest. In photographing this block I so placed the camera that the course taken by it from first to last can be traced.

During the day I went to the east slopes of the coast range south of Mount Caverhill, as on that part of the range it was reported rocks had been thrown down and considerable rents in the ground could be traced. Reaching the place indicated, the rocks proved to be conglomerate in the older series of beds, which are of old Secondary or Palæozoic age. These form a rough rocky ridge trending south-east that at 1,100 ft. above the sea overlooks yet other spurs of the range at a lower level. On the point of the spur the conglomerate is at least 40 ft. in thickness. It forms a nearly vertical face on the south-west side of the spur, and on the opposite side a steep slope, the crest being crowded with loose jutting rocks from 6 ft. to 15 ft. in diameter. Several of these blocks were shifted by the earthquake, but were prevented from rolling down the steep slope by others, more firmly rooted, in front of them. Many varying from 5 to 20 tons in weight, not so impeded, had rolled down the hill-slope on each side of the ridge. Some of these we could see; others had disappeared in the gullies below. Specially I noted one mass of conglomerate about 36 tons weight which had set out on the journey downhill, but before it had well started it came against a jutting mass of conglomerate yet greater than itself, which arrested its progress. Many rents crossed the spur in a south-west north-east direction. None of these were more than 6 in. in width, but from the evidence of these and the shifted rocks it was clear that here the earthquake had been violent indeed.

This place would be about two miles north-north-west of the mouth of the Jed River, where the effects of the earthquake were of a less violent character. Elsewhere on the east slope of the coast range no remarkable evidence of earthquake action has been noted. It was along the west lower slope of this range that in the Cheviot district the most violent action of the earthquake was manifested.

Waiau, 7th December.

From Cheviot it had been my intention to go to Stonyhurst, where it was reported that the first of the earthquake series had been very severe, and had done considerable damage. On consideration I foresaw that some time must be spent in the district

north of the Waiau-ua, between the Mason River and the coastline, and I therefore determined to send my assistant to Stonyhurst, which I did; and by way of Waikari, Culverden, and Rotherham I came to this place yesterday. At Waikari the earthquake of the 16th November did some damage, but this was of little consequence compared with what happened on the Cheviot Estate. At Culverden apparently no damage was done, nor was there much damage done at Rotherham. Between Rotherham and the Waiau the road passes along the plain under the high cliffs terminating the Isolated Hills on their western side. Due to the earthquakes many rocks had fallen, but these cliffs are liable to rapid waste by the fall of large masses of the soft calcareous sandstone of which they are composed; and, although a great number of rock-masses were thrown down by the recent earthquakes, the fall of these do not demonstrate a greater violence of the earthquake along this line than at many places in the neighbourhood, where the evidences appearing were less.

At the Waiau the earthquakes of the 16th November were severe, but the damage resulting was not great. Chimney-tops were thrown down, and in the store and hotel there was some loss by the breakage of bottles, &c. The houses generally suffered only in the loss of part of the chimneys; even houses built of cob were not seriously injured; in one case only I noted rents in the walls of a cob house which were said to be caused by the earthquake. The great shock is described as coming from the north, preceded by a loud rumbling sound, the ground being visibly affected by a wave-motion.

Waiau, 8th December.

Threatening weather interfered with my plans for to-day and tomorrow's work. To-day I intended going to the Stanton Valley to examine the lake formed by the upheaval of the river-bed; but, agreeable to appearances, I went the lesser distance to Highfield Station, where report had it that an earth-disturbance of an extraordinary character had taken place. It was said that a volcanic outburst on a small scale had taken place in the near vicinity of the men's hut.

On arriving at the station I made inquiries as to what the nature of the occurrence had been, and from the station carpenter learned that in the morning of that day he heard the report and saw a cloud of smoke or dust rise from the place whence the noise proceeded. The report was heard by others in the station hut, and the face of the terrace was examined under the belief that a considerable hole in the ground would be discovered. Nothing at all corresponding to what was expected could be discovered, and till my arrival in the afternoon the search was abandoned.

I got the carpenter to point out from the place where he stood the position, or at least the line, from which the so-called smoke issued, and this line I followed along the face of the terrace in the hope of determining the actual point of the explosion. There was thick vegetation (grass) on the face of the terrace, and it was clear that the cloud of dust that accompanied the report could not have arisen from beneath this without there being evident signs of disturbance of the grass at the particular place. No such indications were discoverable, and the line was followed till a small slip about 12 ft. square was reached. On this there was no grass, and I searched carefully for indications of what had happened. Over the extent of the slip there was no disturbance of the surface other than might be attributed to the trampling of feet of men or of horses, and for the moment it seemed as though I must give the search up. I had almost done so, when on following a little further along the line pointed out by the carpenter I found a small patch not more than 2 ft. square which, otherwise without grass, had one cocksfoot tussock growing in the middle of it. This had been recently uprooted almost to the last fibre of the roots. The plant, lying on the down slope of where it grew, was not in the least wilted, but quite fresh and green. Therefore it had been uprooted that morning or some time during the day.

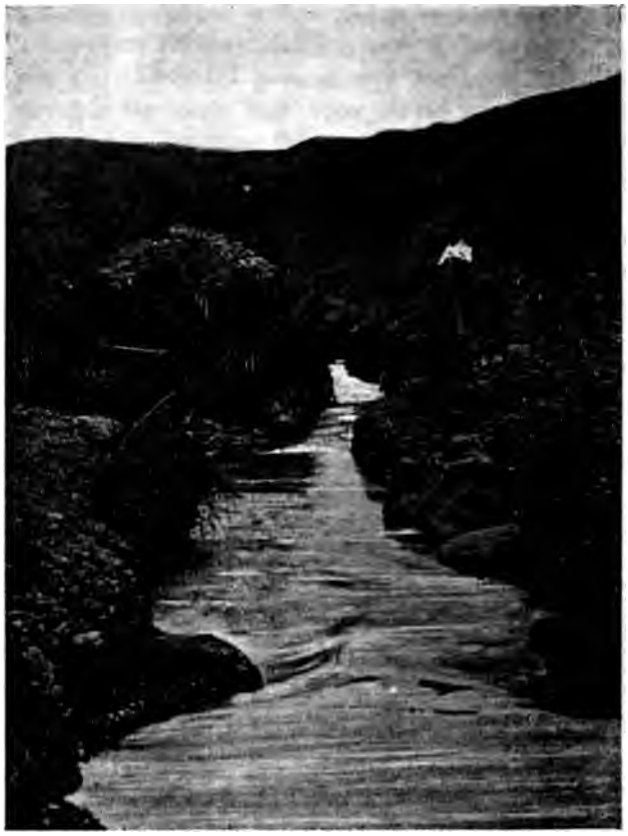
I carefully examined the surroundings for signs of the recent presence of man or horse, or any cause whereby the tussock might have been uprooted other than by an explosion from below; but I could find none, not even in the plant itself, of which not a blade was injured. Satisfied upon this point, I next examined the site on which it had grown. The gravel for a length of 7 in. and a breadth of 5 in. was disturbed and loose; over the surrounding area it was hard and compacted, being the outcrop of the stratum of gravel forming the upper part of the terrace. On the uphill side the boundary of the disturbed part was a straight line, or as nearly straight as the nature of the material would admit of. On the down side and at each end the boundary of the disturbed ground was more irregular. I dug easily with my hand into the loosened gravel to a depth of 5 in. or 6 in., and in this I satisfied myself that the ground was disturbed to a greater depth than the roots of the grass had penetrated to. This done, I came to the conclusion that I had discovered the place from which the carpenter had seen the smoke issue from the face of the terrace, and I also satisfied myself that the tuft of cocksfoot grass was directly in the line pointed out by the carpenter. I was now assured as to the facts of the case. For an explanation of the phenomenon, as this has close connection with the booming sounds common throughout the Amuri district, I shall

deal fully with the question after having marshalled all the facts in the report that I hope to present on the conclusion of the present examinations.

Waiau, 9th December.

Examined the Stanton Valley from its junction with that of the Waiau-ua to the foot of the long cutting on the road from Waiau to Mendip Hills Station and the east coast. The Stanton, rising from the east slopes of Mount Cookson, drains also the western end of the Mount Stuart Range, and, flowing south and south-west through a hilly country, joins the Waiau-ua just above the gorge between Mount Parnassus and the Lowry Peaks Range. Evidences of recent earthquakes appear along the valley up to and beyond the point where the East Coast Road leaves the river-bed. In the lower part the Stanton has cut through rocks of old Secondary or Palæozoic age, and rents in these are the first indications of the earthquakes met with. These rents run across the valley, and on its west side have wrecked a rocky point abutting on to the river, and were also serious where they cross the road-line. A mile and a half higher up the valley serious rents appear in the shingle-bed of the river, and are traceable under the waters of the stream close to one of the crossings. These, however, will disappear by being filled when next the river is in flood.

About four miles up the valley Tertiary strata succeed the Palæozoic rocks, and a little above the junction of the two formations is the place where, by the upraising of the river-bed, the stream is dammed: a long winding lake, 25 chains in length, has been formed. The raising of a portion of the river-bed and the formation of the lake was a result of the earthquakes of the 16th November last. The earthquake, no doubt, was the primary cause, but the obstruction to the flow of the water of the Stanton was immediately due to the occurrence of a large slip from the hillside on the north-west side of the valley. This, set in motion by the earthquake, pressed against the Tertiary strata at the foot of the slope, and underlying the shingle of the flat on the east or left bank of the river, and the material of the slip, instead of overrunning and covering up the surface of the low grounds, compelled this to rise, and at the same time bodily pushed the raised ground forward. Thus the bed of the stream, which before the earthquake had a bend in against the foot of the hill, from which the slip came, was pushed eastward, so that after the earthquake it was straight between points above and below the slip. The shingle of the river-bed was above the level of the dammed water some 7 ft. or 8 ft., and the water in the lower end of the lake, though partly lowered by an artificial cut then being made, was still 10 ft. deep. I was led thus to believe that the total



avation to drain Lake formed in Stanton Valley by Earthquakes of November, 1901.

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elevation of the river-bed was about 17 ft.; but while I write this I have learned that a pool of some depth existed just above what is now the slip, but that there was current at and for a little below the ford, and thus, if the depth of water at the ford be added to the present depth of the cutting through the raised bank, this would make the amount by which the river-bed was raised not more than 12 ft. This is approximately the height to which the ridge on the flat east of the creek has been raised.

This raised ridge has a very steep slope on the east side, and the grassed surface is broken and telescoped one piece over another in a most extraordinary manner, and it is evident that between the east slope of the raised ground and the creek-bed in its present position there is far more turf than would cover the area. The workmen engaged in lowering the waters of the lake were under the impression that the moving cause had been directly underneath the uplifted ground, but I judged differently, and, as I believe, have adduced sufficient proof that the slip from the hillside was the true cause, and that this acted in the manner which has been described. Before the draining of the lake was commenced the dammed water extended upwards along the bed of the stream a distance of 25 chains.

Waiau, 20th December.

On the 16th instant I went from the Waiau to Mendip Hills, and by the way noted that the flood of the 13th and 14th burst the barrier that held back the waters of the Stanton, the cause of which I have described in the preceding letter. When I more particularly examined this obstruction to the flow of the waters of the Stanton men were engaged in making a deep cut along what had been the bed of the stream. I have already referred to this as being some 12 ft. above the bed of the Stanton at the ford above the slips; but the flat to the east of the raised part is at a considerably lower level. When the flood came the cut made could not contain the volume of water that passed down the valley. Thus the lake rose and overflowed the flat ground to the east of the raised ridge. Breaking the surface close alongside the eastern base of the ridge, a new channel was rapidly formed and speedily cut down to such a depth that the lake was drained to below the level of the ford, and all further excavations along the old channel became unnecessary.

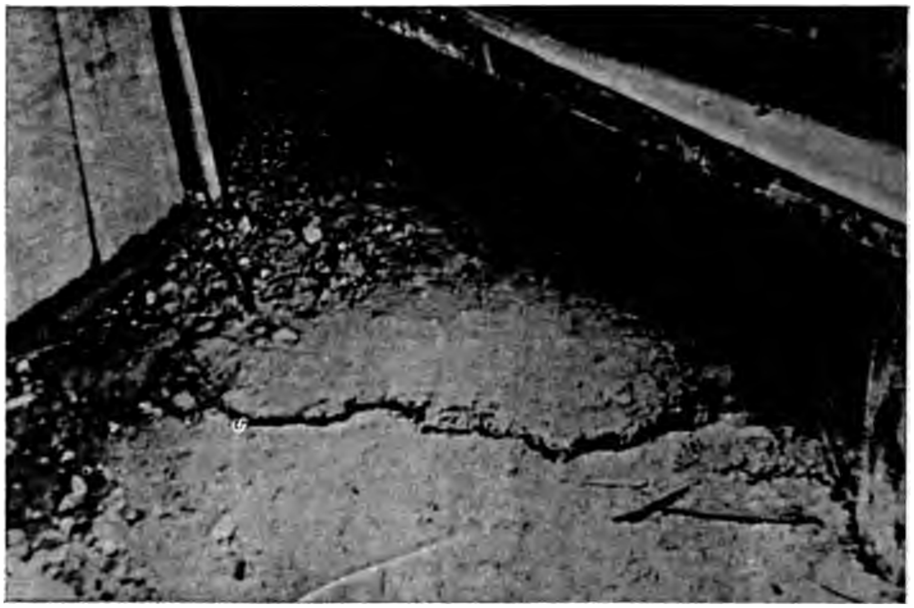
From the Stanton the road to Mendip Hills and the east coast by a long cutting rises on to the crest of the range intervening between the Stanton and Leader Valleys. This cutting is partly in Tertiary clays, partly in old Secondary or Palæozoic rock; but, whatever the rocks it traverses, there is not the least sign of earth-rents on it from where it leaves the Stanton at 450 ft. above sea-level to where it gains the crest of the range at 900 ft. From the road-line

on the range many slips from the precipitous banks of the Stanton could be observed at places higher than the valley was followed upwards, and just before reaching the foot of the long cutting there was noted a specially large slip from the side of a low terraced hill, which an old channel of the Stanton had isolated from the ranges on the north-west side of the valley. This hill was formed of Tertiary rock covered by shingle, and the whole north-eastern face of it formed a talus-slope of huge blocks of rock.

Descending, by way of Long Valley, the east slope of the range, not till within a mile of the junction of the Castaly with the Leader were any signs of earthquake disturbance detected along or near the road-line. The range crossed by the road is a north continuation of Mount Parnassus, and is formed of old Secondary or Palæozoic rocks. On the lower eastern slopes of this rest Tertiary clays, sands, and pebble-beds, alternating with coarser sands, sometimes passing into conglomerate. Entering upon these rocks, forming terraces and downs having steep banks on the north side of the Castaly, and also along the bed of the stream, rents began to appear, but none of them were of a particularly noteworthy character.

On entering the Leader Valley the road turns up-stream and runs along a flat of considerable extent. Rents appeared on this crossing and running parallel to the road, and on the east side of the valley many large slips from the terrace bluff and hill-slopes could be observed. For three miles the road continues along the bed of the Leader, beyond which distance it ascends a high terrace, and thus reaches on to the Mendip Station Flat. On passing up the face of this terrace three rather serious and some lesser rents crossed the road, and to the right and the left points of spurs and hillsides were seen to be considerably disturbed. From the brow of the terrace to the station little or no effects of the earthquakes were to be noted, nor at the station itself was there at first sight anything remarkable to be seen. There were no gaping fissures, and not a building on the place had been thrown down. Chimneys, of course, were all down, and some of these in their fall had crashed through the roofs of the buildings. On closer examination it was soon evident that the damage to buildings and their contents was much greater than at first sight appeared.

The woolshed, stables, and men's quarters have escaped without material damage. The station house and buildings immediately adjacent tell a different tale. The main building consists of four distinct erections closely connected with each other. On the south-east of the main building are three detached lesser buildings, and opposite, a chain or a chain and a half to the east, are sheds, a poultry-house, and more to the north, in the garden, two glass-



Earthquake Rents under Station-house, Mendip Hills Station.

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roofed hot-houses. The main buildings extend nearly north and south, and transverse to this, at each end, are more recent erections.

The interior of the north wing showed clearly the great violence of the earthquake. This was a weatherboarded house resting on wooden piles. Between the rooms a chimney formed of cement concrete rose through the roof. The chimney-top fell through the roof into the eastern room, the bedroom of Mr. and Mrs. Rutherford. With the top of the chimney the middle part under the roof fell also, smashing practically the contents of the room. In the western room the damage was not less. This was the drawing-room of the house, and had been newly furnished. The rooms were cleared by the time I had an opportunity of examining them, but the contents formed part of a heap of broken furniture, &c., which, piled under a verandah, might have amounted to three dray-loads, of which not one article had escaped damage beyond repair. Due to excessive vibration during the earthquake, the house partly left its foundations, and the walls departed from the plumb, and still remain so. This is particularly well shown in the architraves and casements of the bay-window of the drawing-room and a general view of the front of the house. In both rooms of the north wing the floors were broken, and in pulling down the lower part of the chimney it was discovered that the ground was rent immediately under the middle part of the building. With some difficulty I managed to take a photograph of this.

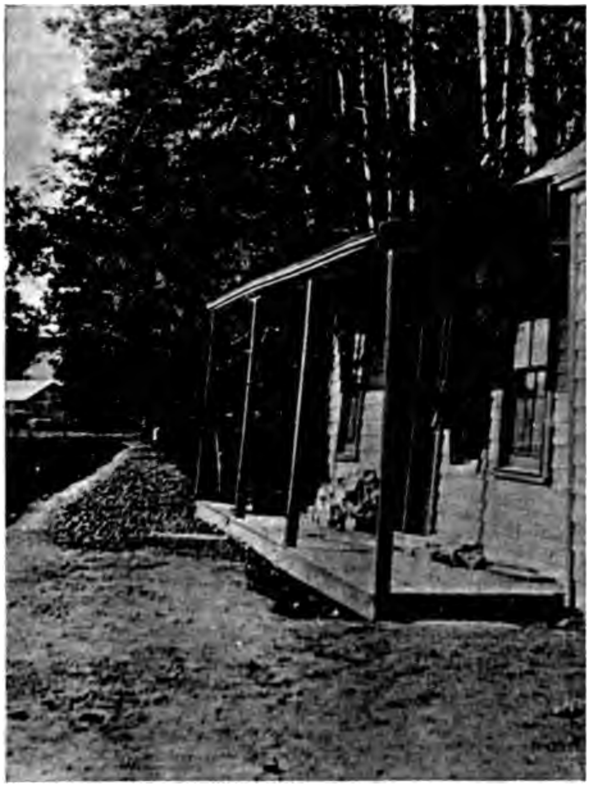
The middle part of the house constitutes the older part. This, with the kitchen and pantry at the back, escaped the extreme violence of the earthquake in a manner altogether remarkable, seeing that the south wing suffered severely. The wherefore of the trifling damage to the middle part was for a time a puzzle to me. The explanation will be given farther on. The brickwork in connection with the kitchen-range and hot-water apparatus was demolished, and was being rebuilt at the time of my visit. Thus I did not see it, as it was immediately after the earthquakes of the 16th November.

The southern wing of the house is a building of considerable size, 28 ft. by 33 ft. This rested on a concrete foundation, walls externally, and piles under the interior part. The north-west corner, which was in close contact with the central part of the house, was shifted by the earthquake 29 in. to the south. This shift overturned the cement piles on which the house stood, and partly broke down the outer foundation walls. The building itself does not appear to be much injured, but the doors and windows are all jammed in their frames, and this part of the house has not been entered since the occurrence of the great shock on the 16th November last. A look through some of the windows shows the furniture contents tumbled

about in a most disorderly fashion; yet, singular as it may appear, not one pane of glass was broken in this part of the house, and all over the house and adjacent buildings window-glass seems to have escaped destruction in a most marvellous manner. This is the more remarkable seeing that within 2 or 3 yards of some of the windows a closed gate was burst open, and this had to be, and was, done by the breaking of the hasp catch, the tang of which was solid iron ⅜ in. square.

Of the detached buildings the dairy store and butchery store formed a line of buildings running at right angles to the direction of the main building, and, though damaged to a considerable extent, they are yet less so than the dwellinghouse. South of the main building, and in line with the back part of the station-house, were two cottages—one of them used as wash-house, store, and photographic rooms; the other was occupied as a dwelling, and was divided into five rooms, and a concrete chimney was built between the main room and the two bedrooms to the north. This building sustained the full force of the great shock, and on close examination as it at present stands it is evident that it has been bodily thrown into the air, and, not coming down in exactly the place where it formerly stood, resulted in broken walls, floors, and ceiling, and generally the most complete wreck, as far as wooden houses are concerned, that resulted from the earthquakes. The house was built on a gentle declivity, sloping to the westward, and stood on wooden piles, which on the down side are 18 in. or 20 in. above the ground. The eastern piles were nearly level with the surface of the ground.

Mr. Rutherford, jun., told me that this building was not brought to its present condition by the first great shock of earthquake, but that on the occurrence of succeeding severe shocks it kept sinking in the back part to yet lower levels, and thus gradually it became more twisted, and the floors and ceiling got more and more broken. I do not wish to discredit this evidence, for it is perfectly consistent with the other facts observed. That it left the piles by an upward movement which was nearly vertical is shown by the fact that the nails spiking the lower plates to the piles were clean drawn without being bent, and without pressure to one or other side, and, while the house was turned from a north-and-south direction of its longer side to a direction more south-east and north-west, this was done without any of the spike-nails making a mark on the top of the piles, which must have happened had the house simply moved forward to the east-south-east. In all cases in which houses moved without being thrown into the air the piles were dragged in the direction of the movement of the house. In



t Mendip Hills Station shifted and wrecked by Earthquakes of 16th November, 1901.

[To face p. 67.

this case the piles that should have most readily yielded, because the highest above the ground, still remain in a perfectly vertical position. Further, not only was the house thrown into the air, but while clear of the ground it turned so as to alter the direction of the sides and ends, for the mere sagging of the walls and the breaking of the floors by the action of after-shocks, while it might draw south the north-west corner of the house, at the same time would have drawn the south-east corner to the west. Conformable to a true rotary movement, the south-east corner has been moved 20 in. to the eastward, and in so doing has overriden the pathway in front of the house, which was a little higher than the floor of the house. Not only was the house turned in the direction indicated, but while off the piles it was thrown to the eastward some 5 in.; and this movement of the house to the eastward undoubtedly was the cause of the fall of the chimney, the top falling on the west slope of the roof, though much of the interior part of the chimney fell to the eastward. When the house again rested on the ground it was 5 in. more to the eastward, and the lower part of the chimney had acted as a pivot on which it turned. Immediately opposite the middle part the bottom plate on the west side of the house was clear of the pile, with the result that on this side towards the south the walls were clear of or pressed the piles outwards towards the west. Of the condition of this cottage I need say no more; imagination and a couple of photographs will supply the rest.

It has been noted that the central part of the station-house suffered comparatively little as compared with the north and south wings or the cottages adjacent, and there is an apparent reason for this immunity of the central part. Though scarcely to be traced at the time of my visit, a line of earth-rent was opened along the east edge of the pathway leading from the house to the woolshed and stables. This with strange exactitude ran along the water-table of the formed pathway from the junction of the south wing past the cottages already described, and for some considerable distance towards the woolshed, how far I did not exactly determine. Towards the north it went no farther than the south wing of the station-house. Here all traces of it were lost; and, although a small building and the cement pavement outside, east of the kitchen, were in the direct line of its northern continuation, neither the small house nor the cement pavement were in the least disturbed.

The southern wing was the part of the house the most displaced from its foundation, the shift south of the north-west corner being 29 in. This is rather remarkable seeing that the part of the house with which the south wing was in contact was not shifted at all. The explanation seems to be that at the north-east corner of the south wing

the rent altered its course from north and south to east and west, and so continued to a point on the lawn just west of the gravelled front of the house. At this point it again altered its course to east-north-east, which line carried it under the front part of the north wing, beyond which it seems to have resumed its north-and-south course. This being so, it will be seen that all the buildings on the west side of the line of rent suffered the most, whilst those on the east side suffered less, and not greatly except as to the contents of the rooms. The two glass-roofed houses in the garden being on the east side of the line were not to any extent injured. The lesser of these, however, must have rocked considerably, if, indeed, it was not completely thrown into the air. During the great shock two panes of glass on the roof were broken, and that the interior might not be lowered in temperature the gardener placed a sack over the opening, weighting the same to keep it in place. Succeeding shocks displaced the sack, which in its fall got under the house just over one of the piles. The sack now covers the top of the pile, and the house has all the appearance of never having been shifted, but it must have shifted sufficiently to admit the sack between the wall-plate and the pile.

The force of the earthquake was undoubtedly great at Mendip Hills Station, but more to the north this rapidly lessened, and beyond a mile and a half in that direction there is little trace of its action. The station-house is supplied with water from a spring in the hills about two miles distant. The pipe-line carrying the water was broken at three or four places within 10 chains of the house, and but once in the remaining distance to the source of supply.

On the banks of the Leader, at a point north-west of the station-house, there is a high cliff the base of which is washed by the stream. Before the earthquake this, though steep, was covered with native shrubs and small trees. During the earthquakes of the 16th November great falls from this cliff took place, burying beneath the *débris* the bush that was not carried away, and almost obliterating all signs of bush having existed. This, as a landslip caused by the earthquake, is in point of size next to those on the Bluff Road between the mouth of the Jed and Port Robinson.

Waiau, 18th December.

Learning that the effects of the earthquakes, as compared with what they were at Mendip Hills, were much less at Hawkswood and Ferniehurst Stations, I concluded that it was not necessary to visit those places, and the threatening state of the weather confirmed me in this resolve; but before returning to the Waiau I determined to visit Parnassus Station, where the force of the great shock, it was

reported, had been very severe, and where houses had been wrecked and thrown down.

Before leaving Mendip Hills Station I examined immediately east of the station-house, and on One-tree Hill discovered a great many small rents in the ground, all of them trending in the direction of Ferniehurst Station. There might have been twelve or fifteen of these rents over a breadth of 25 ft., but the widest was not more than 2 in. Some of them had a vertical displacement of some 2 in. on the south-east side of the rent. The ridge of hills on which these rents appear is formed of Tertiary strata, and these rents are therefore in solid rock.

In passing down the Leader Valley the numerous slips and surface-rendings on its eastern side were again examined. Mr. Rutherford reported that the earthquakes had been unusually severe along this side of the valley, breaking the wire fences at numerous places, or in some cases carrying them away bodily. I did not by close examination verify these facts, but from the valley saw that some of the steep hill-slopes had the surface of the ground much broken by what appeared to be shallow rendings that were not likely to penetrate to any great depth. This was about a mile and a half below the station. A little further down the valley a very large slip which had taken place many years ago, and which had become solid under ordinary circumstances, had a second time been set in motion by the earthquakes, and yet farther down near to the Four Gates the gravel cliffs on the immediate banks of the river had shed a good deal of gravel and top soil, which now rested at their base, but in this respect were more imposing than important.

About a mile below the Four Gates the river turns to a more south-east course, and in the angle formed the high bank on the east, consisting of well-compacted sands and pebble-beds of Tertiary age, is much shaken, and true earth-rents begin to appear. At the crossing of the river some large blocks, 8 ft. to 10 ft. square, have been wrenched from the solid, and now lie at the foot of the cliffs. A little farther down-stream numerous rents appear in the gravels of the river-bed, many of them from 8 in. to 12 in. wide; they are on the open river-bed, and not, as at Cheviot, between the soft valley-bottom and the harder bounding terraces, though even here such rents are not wanting, as, for instance, at the last crossing of the river on the road to Parnassus. At the bend in the Leader above referred to the hill-slopes, especially on the west or Mount Parnassus side of the valley, show numerous large and long extended earthquake rents that run in a westerly direction. These are nearly vertical, and clearly cut the spurs to a great depth. They are true

earthquake rents, and not merely the breaking of the surface and the forming of a shallow rent as in numerous cases already cited.

On reaching the lower part of the valley, whence a depression runs along the west slope of the Hawkswood Range to the Conway, thence till reaching Parnassus Station all signs of earthquake action ceased, which is remarkable considering the violence of the earthquake not three miles distant from the station-house.

At Parnassus Station considerable damage was done to the station-buildings. Such parts of the station-house as had cob walls were thrown down, and there was consequent appearance of great wreck; but buildings in wood were not seriously damaged. Three cob-walled cottages were completely thrown down, and one of these, a little west of the woolshed, had been occupied by six men the night previous to the earthquakes of the 16th November. This, fortunately, at the time of the great shock had no one in it. The walls fell for the most part towards the interior of the house, and the roof came down to within a few inches of the ground, and escape from the fallen building, except by burrowing, would have been impossible, and this probably would have been the less serious consequence to any one who might have been under the roof at the time the earthquake took place.

It has been remarked that there were no earth-rents formed in the immediate vicinity of the station homestead, but Mr. Giles, manager of the station, pointed out a series of earth-rents on the banks of the Waiau-ua, about midway between the station-house and the junction of the Leader. Between where these rents began and where the Leader joins the Waiau-ua a low river-flat extends under the higher terrace, which it was proposed to cross in order to reach the mouth of the Leader, but Mr. Giles assured me that this flat was dangerous to traverse on account of earthquake rents, and that to ride a horse over it was impossible.

Conway, 19th December.

Yesterday I returned to Waiau Township, after which it was a matter for consideration what was next to be done. So far I had failed to discover the real cause of the earthquake shocks that had prevailed over the district since the middle of November. At first, and before reaching Cheviot, I thought the disturbances were due to movements along the line of the Great Clarence fault between the upper Hanmer and the Waipara River, and that the earthquake shocks over the district to the east of this line had their origin in movements along the great line of fault. There was some warranty for this supposition, seeing that the like thing happened in 1888 between the source of the Hanmer and Kiwi Creek, in the Hope

Valley. At that time, and south of the line indicated, the country was much disturbed to very considerable distances, while to the north of the line the more violent effects of the earthquakes rapidly died away. In the present case, as there was comparatively little disturbance in the Upper Waipara, at Heathstock, Waikari, and Culverden, and places along the line of fault or in its near vicinity, I was forced to the conclusion that the disturbance at Cheviot and along the Leader Valley had a cause other than the reopening of the Great Clarence line of fault.

Driven from this position, I speculated as to whether or not the cause arose from an eastern extension of the line affected in 1888, and various reports seemed to give colour and probability to this supposition. To investigate the likelihood of this was partly the reason of my visit to the Upper Leader Valley, and to learn the truth respecting persistent reports of great rents on Mount Cookson and in the country to the east. This, however, is not the true continuation of the line of fault along the Hope and Waiau-ua Valleys, which, traced to the forks of Lottery Creek, if continued eastward on the same line, would pass to the north of Mount Cookson and along the northern slope of the Mount Stuart Range to and across the Conway River, and thence to the coast-line at Goose Bay. I had a conversation with some men who had been working on the Claverly Station, through which this supposed continuation of the fault-line runs, and they described the earthquakes as having been very violent in that part; and I assumed that a continuation of the east-and-west line of fault from Lottery Creek to the coast-line had been reopened, and was mainly responsible for the disturbances that had taken place in the country to the south of the line.

To investigate these matters I came to the Conway to-day, but saw nothing supporting the theory I had formed. There was not the least sign of the continuation of the fault-line in the direction indicated. On the contrary, it was evident that, as formerly determined, the fault-line at the forks of Lottery Creek alters its course, and, assuming a more northerly direction, passes along the east slopes of Mount Sherwood to the Upper Mason River; thence north-west of the Whale's Back it reaches into the watershed of the Conway, and runs along the western bank of the Towy River to the junction of that with the Conway.

In the Towy Valley the line of fault is marked by a series of gigantic slips, that form a very marked feature of the mountain scenery of this part. The last of these slips terminate where the line of fault crosses the Conway. On the north-east side of the Conway the fault-line runs along a deep valley for a distance of fully half a mile. Thence towards the north-east it crosses a series of

spurs and gullies, sculpturing the south-eastern face of the Goat Range, to the Charwell River. At the Charwell the main line of fault is joined by another having a more easterly direction. The principal line from the saddle between the Towy and the Mason Rivers to the Charwell River bears N. 10° E. magnetic, and this line, if continued, would pass to the eastward of Black Hill, and across the sources of the Linton River and Cribb Creek to the source of the Kohai and the saddle on the western shoulder of Mount Fyffe. The further continuation of this line need not be here considered. Over the ground that has been traced it is at places sufficiently well marked, and at other places it is somewhat obscure.

The eastern branch is very clearly seen on the low spurs opposite Green Hills Station, and along the course of Greenburn it is remarkably clearly displayed on the west side of the valley. At the foot of the long cutting by which the road to Kaikoura descends to and crosses Greenburn the road at one point is practically on the line of fault. This is continued to the north-east past the Shearing Reserve, past Swyncombe, and across the Kohai River to the downs and lower slopes of Mount Fyffe. This is the line of fault better known as the Kaikoura fault.

Nowhere along either of these two lines did any fresh ruptures or displacement of the strata take place, though it was noticed that from the great slips between the Towy Saddle and the Conway great clouds of dust were raised. The only rending of the ground that took place in this part of the Conway district was on the big cuttings leading north-east from the river-bed to the accommodation-house, and this was not more than a rent along the under unsupported side of the road. Neither of these fault-lines having been reopened or even seriously affected, it is plain that the earthquakes did not originate in disturbances along either of them.

There is yet another line of fault in the Green Hills district. This leaves the Kaikoura line at the southern base of Mount Fyffe, more strictly near Swyncombe Station, but is not clearly marked till it crosses Greenburn and enters on the higher land west of Monkey Face. In this part, and thence along Limestone Creek to the junction of that with the Charwell, it is very clearly marked. This fault is between Palæozoic rocks to the west and Cretaceous rocks on the east side of the fault-line, and along the junction of the two formations there is involved a very coarse breccia, composed chiefly of masses of Amuri limestone. This line, if continued, would not, without alteration of its direction, reach into the valley of the Leader, and it may thus be said that the late seismic disturbances of the district between the Conway and the Hurunui is not referable to any known line of fault.

Wellington, 25th December.

From the Conway I came by coach to Kaikoura, hoping that some further information might thus be obtained. Nothing of any importance was gleaned, and, there being an opportunity of returning to Wellington direct from Kaikoura, I availed myself of this, and reached Wellington on the morning of the 25th December.

I have, &c.,

The Under-Secretary for Mines. ALEX. McKAY.

INFORMATION GLEANED FROM SOURCES OTHER THAN PERSONAL OBSERVATION.

In the foregoing letters I have given as little as possible of hearsay matter. Yet there are many things which, although not directly coming under my notice, are to be regarded as truth, and deserve to be recorded. Some accounts may to a certain extent exaggerate the truth, and yet are worthy of a place in this report; and the reader may accept them *in toto* or discount them, as may be deemed advisable.

The recent earthquakes that disturbed the Cheviot and Amuri districts commenced on the morning of the 16th November, 1901, and the accounts appearing in the Press of the colony under that date, though indicating an earthquake of unusual severity, were not of a sensational kind. These accounts gradually became more alarming, and by the middle of the following week the Christchurch papers had invented the phrase "stricken Cheviot," and the number, names, and destination of each batch of refugees, consisting mainly of women and children, was carefully given. Relief committees were formed, lady members of which received and arranged for the convenience of the women and children. Public subscription-lists were opened, and it was even thought fit to send a supply of bread to the supposed starving population made homeless by the earthquakes. The bakers' ovens had indeed been destroyed, but the stock of flour was in no sense lessened. Camp-ovens and frying-pans were for the most part uninjured, and home-made bread and scones were still a possibility. None of those who remained in the Township of Mackenzie or its surroundings had occasion to go without a meal, not, at least, owing to what had happened during the occurrence of the earthquakes.

The exact time of the great shock is variously stated, but it appears to have been at 8.12 a.m. on the morning of the 16th November. Most of the inhabitants had finished breakfast and had

set about the business of the day. There has been much, perhaps unnecessary, speculation as to what the results would have been had the earthquakes of between 8 and 9 o'clock happened at an earlier hour or during the previous night. Without question there may have been serious loss of life, and many houses to a certainty would have been burned down. Some accounts state that the great shock came suddenly and without warning; others that it was preceded by a loud rumbling noise; and yet again there are others who state that a slight shock of earthquake preceded the great shock. All agree that the atmosphere was still and dead calm at the time of the occurrence of the great shock.

The general belief is that the earthquake came from the eastward or from the sea, but this belief is the result of observing that in most cases loose articles tended to move towards the west or north-west. In this case the facts are admitted, but the reasoning therefrom led to a wrong conclusion, as there cannot be a doubt that the shocks originated in and came to Cheviot from the north-west and north. All those who heard the preceding noise agree that these came from the northward. At the Waiau these noises, by an appreciable interval, preceded the commencement of the great shock.

Lest there should be doubt as to the direction in which the earthquake shakes were propagated, I may once more cite the direction in which movable bodies were thrown on being displaced from where they were prior to the great and succeeding shocks. In and around the Township of Mackenzie a preponderance of evidence showed that the progress of the earth-waves was from north-west to south-east, but there was evidence also that it came from the west, and also in two cases that it came from the north-east. The testimony of individuals also agrees with the observed facts that the disturbance as a whole had a general north-west and south-east direction. That in certain cases displacements took place in a nearly east-and-west direction, or that some buildings fell or were thrown to the east, does not affect the general tendency of the evidence on this point. Lest, however, more precise evidence should be required, I may here recount what was told me by Mr. Giles, manager of Parnassus Station, on a reference to what had been the true direction of the earthquake shocks.

Some days after the occurrence of the great shock, and while yet violent earthquakes were of frequent occurrence, a telephone message was being transmitted between Parnassus and Mendip Hills Station, or a station to the north of Parnassus. What station I am not quite sure, as I did not record the story in writing at the time I was told it. While the message was being transmitted the person at the northern station experienced a shock of earthquake, and at

once, on its passing, asked the Parnassus Station, "Did you feel that?" meaning the earthquake shock. The reply was "No"; but immediately afterwards — the shock in the meantime having reached Parnassus—the amended answer was "Yes, yes," as the shock passed away to the southward. In the Waiau Township the noise preceding the great shock was distinctly ascertained to come from the north, and this preceded the earthquake itself by some little time, the earthquake coming from the same direction.

Against these evidences, however, may be placed the fact that some buildings were moved towards the south, which may be taken to mean that the earthquake came from that direction.

Whether the surface of the ground was rent or torn, or even where this did not take place, it was greatly agitated, and a rolling wave-like motion appeared to pass over it. At many places the surface appeared to be agitated by a swirling motion, which was very perceptible where scrub or tall grass covered the ground. Tall trees moved upwards and downwards in the vicinity of where the swirling motion was observed; at other places their tops were bent forward to the westward, and sometimes they leaned in this direction 45° to 50°. The waves affecting the surface of the ground are never stated to have been of great height, and, as far as I could gather, were seldom more than 4 ft. from crest to crest. This relates to the vicinity of the township, but to the westward of Mackenzie disturbances of this kind must have been of far greater magnitude. In this connection a strange story is told, and, though it did not come to me direct from the observer, I had it from a reputable source, and from those who believed in its truth. A belt of trees stretches north and south across the plain about a mile west of Mackenzie, to the westward of which is a farmhouse, from which, under ordinary circumstances, the township cannot be seen. Whilst the great shock of the 16th November was in progress the Township of Mackenzie could be distinctly seen over the tops of the plantation trees. I did not visit the farmhouse to ascertain by how much the ground must have been raised or lowered, or the trees bent forwards or backwards, to enable a view of the township to be obtained, but I judged that the inequality of the surface movements must have been much more than had happened in the immediate vicinity of the township. At the time I paid but little heed to the tale, thinking it a highly improbable story, though not doubting the sincerity of those from whom I had it.

In connection with the gyratory movement of the surface of the ground which was observed at many places, I may mention that this was particularly noticable on the west slopes and along that base of the coast range, and, curiously enough, where such motion was observed

no earth-rents were formed. In connection with the farmhouse of Glenkens, an excavation had been made in the face of a steep bank which, properly roofed over, served as a dairy. Underneath the roof the walls of the excavation were not plastered, but to prevent dust reaching the milk and dairy produce large packing-cases were ranged along the back wall. This somewhat primitive dairy was cool and airy, and served its purpose well. The packing-cases were large enough to hold two milk-pans in the length of the box. One such box with a shelf had four milk-pans in it at the time of the earthquake. The western pans were thrown out of the box and the milk spilled, while those in the eastern end of the box were not moved, and the milk with the rising cream showed no sign of agitation. I examined this dairy, and had explained to me the manner in which the thing had occurred, and to me it appeared that the diameter of the circle in movement need not have exceeded 6 ft. This movement in the particular locality above referred to seems to have been confined to the Cretaceous rocks of the district. Immediately to the eastward these cease, and the slopes of the Mount Caverhill Range are formed of old Secondary or Palæozoic rocks. Over these rents were numerous near Glenkens house.

In the upper valley of the Jed and the Cheviot basin enormous clouds of dust filled the lower atmosphere. Within and near the township this was caused largely by the fall of chimneys, but was also the result of the shaking and agitation of a dry soil, there having been no rain in the district for some months. The fall of the cliffs between the mouth of the Jed and Port Robinson must have produced enormous clouds of dust, as also the falls that took place in the upper part of Swamp Creek, along Frog Hall Road.

Besides the wave-transmission and gyratory motion of the earthquakes, there was also a vertical movement which acted upon substances near and on the surface of the ground as a blow from some depth in the earth. Instances illustrative of this were noted in Scott's Commercial Hotel, in Penberthy's Hotel, and are reported to have occurred in the Mansion House also, and a full description has been given of the like effects of the earthquake as this was experienced at Mendip Hills.

The effect of the earthquakes on springs and underground waters was very marked. Wells that prior to the 16th November had a full supply of water were dried up, and streams whose beds were dry before the occurrence had an ample flow of water afterwards, although in the meantime there had been no rain. On dry flats distant from any running stream rents were formed, and water and sand were emitted in considerable volume. A case has already been noted as occurring on Macfarlane's farm; and more to the west, on the south

side of Swamp Creek, the discharge, in this manner, of water to the surface was very considerable.

Evidence of the same action also was observed on the bed of the Hurunui River below Domett. Sand and water escaping to the surface, as reported in the newspapers, occurred at Kaiapoi; and from the Waiau was reported the extraordinary statement that the bed of the river opened, engulfing the waters of the stream, but, the rents suddenly closing again, the waters were discharged in spouting columns that rose to a height of 200 ft. At the Waiau I made inquiries as to whether this thing did really happen, but could find no one who saw or noted the same.

In the case of Swamp Creek, at Cheviot, it is asserted that the discharge of water was so great that for a time the creek was flooded bank-high. This statement is decidedly an exaggeration. Within a week of the supposed occurrence of this flood I examined the bed of the creek at several places, and I saw no evidence that a flood had recently taken place. That the amount of water in the creek was increased considerably there need be no doubt, but there could have been no flood without there having been traces of this at the time my examinations were made.

In the Waiau district all sorts of accounts were circulated as to the state of Mount Cookson. It was more than once reported that this mountain had burst forth in eruption, but clouds of dust rising from limestone crevices and clay banks on that mountain must be regarded as being the only foundation for these reports.

There is a considerable amount of evidence tending to show that the rate at which the earthquake travelled was a slow one. In Mackenzie a blacksmith was driven from his workshop by the fall of horse-shoes and other light articles from the joists, and had reached the middle of the road in front of the smithy in time to see the chimneys of Penberthy's Hotel fall to the ground. The distance might be 9 chains. At the Waiau the noise of the coming shock was distinctly heard for some little time before the earthquake was felt. On Lyndon Run a party of surveyors were in the field, and observed a cloud of dust rise from the Leslie Hills. Shortly afterwards they experienced the earthquake, and turning to the east could leisurely trace its course east by the clouds of dust that successively rose from the valleys of Lottery Creek and the Mason River, and more to the east by the same means its progress across Mount Cookson. This story is given here to show the slow rate at which the earthquake travelled, and rests on the authority of G. H. W. McClure, District Surveyor, who made the observations here stated, and which have been more fully detailed in the preceding report.

Violent earthquakes in all cases produce a sense of terror in both men and animals, and, though in this connection there may be nothing new to tell, there are still some things that are worth being recorded. With respect to man, during the recent disturbances in the Cheviot and Amuri districts the first impulse was to flee the danger, and there was consequently an indiscriminate rush from houses into the open street or the field. In many cases this could but barely be effected; many were thrown down, and, finding it difficult or impossible to get on their feet again, the will to make the attempt left them, and they remained in a semi-paralysed condition till the greater force of the shock was over. Many have expressed to me the opinion that they could not move, not so much on account of the agitation of the ground, but that they seemed to be spellbound. In other cases frantic efforts were made to get clear of danger in the shape of falling buildings, chimneys, &c. One man told me that he fell to the ground and regained his feet an incredible number of times in the attempt to cover a distance a little more than 20 ft., but he succeeded in reaching his destination and haven of safety, which was a clothes-pole in the back yard of the premises where he dwelt. Others in the same locality gained the street with comparative ease, and as soon as they had reached imagined safety commenced bewailing their all-too-evident losses in stentorian tones and language quite original. In yet other cases, on reaching apparent safety a muster was held, and on it being ascertained that none were missing the opinion was expressed that otherwise all might go to wreck and ruin since, unharmed, the muster was complete.

At Mendip Hills Station the effect of the great shock on the owner, Mr. Rutherford, was somewhat remarkable. At the moment of the commencement of the great shock he was about to enter the woolshed, and had his foot on the step of the door that led to the shearing-floor, when suddenly he was thrown back, but managed to keep his feet, though not securely, for by a series of like stumbles backward he was carried right across the sheep-yard, and only regained equilibrium when supported by the fence of the yard.

At the same place the gardener, on being capsized with a barrow, came to the conclusion that he could not move, nor did so till the advent of a swarm of bees, which quickly convinced him of his ability to rise and leave their company, which latter feat involved some distance and occupied some time.

On the Cheviot Estate the occupier of a small grazing-run was standing near the woolshed yards when the great shock commenced. To prevent his falling to the ground he clung to the top rail of the fence, and while the shock lasted had an extremely lively time of it,

somewhat resembling such experience as may be had on a buck-jumping and somewhat determined horse, but in spite of all the goings-on he stuck to the fence.

Not less exciting at about the same time was the experience of his youngest daughter. She had been to catch a horse, and was leading the animal along the steep slope of a hillside when the great shock began. Suddenly the horse plunged and reared, but bravely the girl held on to the bridle, and the position was such that but for the mutual support both might have been thrown off their feet, and the slope was so steep that had this taken place both must have been precipitated into the gully beneath them. Nor was the danger lessened when the ground rent beneath their feet, and at least one fissure was formed wide enough to add to the danger of the situation. While thus occupied with the horse, and under such trying circumstances, the girl's attention was taken so that afterwards she was able to describe the manner in which the pine-trees surrounding the house were affected by the earthquake.

At the Waiau the hotel cook stood paralysed in front of the kitchen-range while the chimney was being wrecked by the earthquake.

In the same township, in a certain house, the good wife was no further disturbed than to note the exact time at which the shock commenced. In some cases a feeling resembling sea-sickness was the result of the earthquake, and in one instance which came under my notice this was reported as being quite as severe as sea-sickness usually is.

The effects on animals were various, according to their intelligence and temper. Dogs howled and showed the usual signs of fear common to this species, and, long after the first great shock, gave notice that they were far from appreciating the occurrence of an earthquake. Horses, for the most part, plunged and reared as though fain to leave the surface of the earth altogether. Cattle expressed their alarm in loud bellowings, while domestic fowls sought shelter as from the danger of a bird of prey overhead. At one place in the Township of Mackenzie the fowls disappeared and were not seen again for two days after the great shock. At the same place the cow lay down, or, rather, was thrown down by the earthquake, and thus remained bellowing and lowing in most melancholy tones.

With respect to fear in animals, the most remarkable case that came under my notice was that of a horse belonging to Mr. Robert Sloss, of Leamington Valley. Mr. Sloss at the time of the great shock was in the field, and rode the horse in question. Becoming aware that an earthquake of unusual violence had taken place, he

returned to the house to ascertain what had taken place, and how it fared with the family. Arrived at the farm-steading, Mr. Sloss, on putting the horse in the stable, noticed that it trembled considerably, but of this he took but little heed, more important concerns engaging his attention. Proceeding to the house, the horse was forgotten for a time, but in about an hour it was attended to, when it was found bathed in a cold sweat. There were no other horses in the stable at the time, and the continuance of violent shocks of earthquake will readily account for its evident terror and its condition otherwise. The animal was turned out and put in a paddock adjacent to the stable. On being set free at the gate, the horse went no farther than a chain or two into the paddock, when it lay down and died instantly. It is surmised that had the horse been turned out at once, where it could have had the companionship of the other horses in the paddock, it would not have been so stricken with fear, nor would it have died from such a cause as it did.

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